PROCEEDINGS

OF THE

NATIONAL ACADEMY OF SCIENCES, INDIA

1963

VOL. XXXIII SECTION—B PART III

NATIONAL ACADEMY OF SCIENCES, INDIA
ALLAHABAD

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OF THE
NATIONAL ACADEMY OF SCIENCES
INDIA
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REVISION OF BAGNALL'S WORK ON THE GENUS *ONYCHIURUS* (COLLEMBOLA)

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[Received on December 13, 1962]

Introduction :

Since Gervais (1841) many attempts to split up the genus *Onychiurus* into subgenera and "species groups" have been made by Absolon (1901), Handschin (1920) and Bagnall (1949) and others. The last named worker has complicated the concept of taxonomy by introducing a method which cannot be held reliable because of the following reasons : (1) Bagnall's descriptions lack accuracy and are so inadequate that one gets lost in his attempt to place his species correctly in relation to the other well-established species of this group. (2) Most of his species are erected on the basis of highly variable characters. (3) His division of the genus into twentyfive closely related genera without showing any phylogenetic significance has roused a sense of doubt in the minds of the subsequent workers as to their validity Stach (1954) aptly remarks, "Bagnall has created a new genus for almost every species of Onychiuridae".

In view of the above the present author has made an attempt to revise Bagnall's work on the *Onychiurus*.

Description of species :

1. *Onychiurus flavidulus* Bagnall, 1939.

The author (1961) has already synonymised this widely distributed species of U. K. with *O. aurantiacus*, previously known as *Lipura aurantiaca* Ridley, 1880.

2. *O. waterstoni* Bagnall, 1937.

Syn. n. *O. uliginatus* Gisin, 1952
O. sublatus Gisin, 1957

Bagnall described *O. waterstoni* as "a small species coming near *O. armatus* from which it differs in the few vesilces of P. A. O. (18–22)". After examining the holotype and one paratype it is found that the type and paratype specimens have 24

and 26 vesicles respectively and this number is well within the range of number of vesicles possessed by other specimens originally identified as *O. uliginatus* Gisin, 1952. However, the following description presents a true picture of *O. waterstoni.*

Body. Maximum length excluding antenna about 2·03 mm.

P. A. O. With 20–28 cylindrical vesicles separated from each other.

Pseudocelli. $\frac{34 \text{ or } 5 \text{ or } 3/022/33343}{1/000/00000}$; posterodorsal part of head rarely with 5 pseudocelli on one side only.

Legs. Unguis with or without a minute tooth about halfway along inner margin.

Anal spines. Slender, conical, weakly curved and on distinct papillae.

*Text-figures 2, 8 & 11 are drawn in the same scale and the rest are drawn in the other scale.

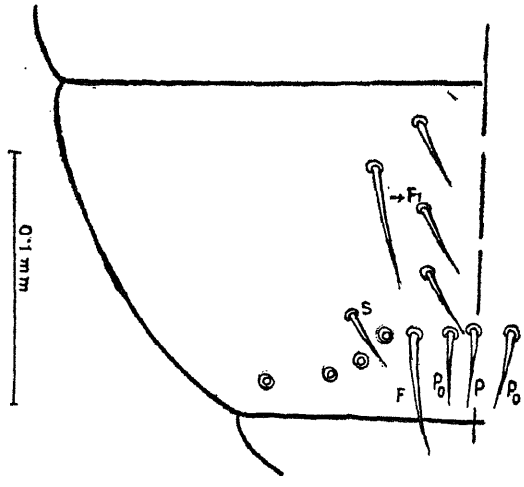

Fig. 1. Dorsomedium part of Abd. V. (*O. Waterstoni*).

Chaetotaxy :

Posterodorsal part of head : As in *O. aurantiacus* (Ridley) Chouduhri, 1961.

Tergite of Th. I. Posterior half as in text-fig 3 ; anterior half with m_2 present or absent.

Tergite of Abd. V- In between seta F of each side usually two microsetae p_o and p_o on each side of middorsal line ; very rarely seta *p* (Text-fig. 1) appears on this segment.

Tergite of Abd. VI. As in *O. aurantiacus.*

Ventral tube. As in *aurantiacus.*

Upper anal valve. Either as in *O. fimatus* Gisin or as in *O. campatus* Gisin (Text-fig. 2).

All other characters as in *O. fimatus.*

The comparison of the holotype of *O. waterstoni* with some specimens of *O. uliginatus* and a few paratypes of *O. sublatus* suggests that these three forms are conspecific. From Gisin's original description it is gathered that *O. sublatus* has 3 pseudocelli on the posterodorsal part of the head and "sub-parallel" chaetotaxy of the Abd. VI. The number of pseudocelli on the posterodorsal part of the head varies a good deal from 3–5 ; with regard to the second difference Gisin's observation has been found to be incorrect. In fact, the chaetotaxy on the Abd. VI of the paratypes of *O. sublatus* lent by Gisin is parallel as in *O. waterstoni*.

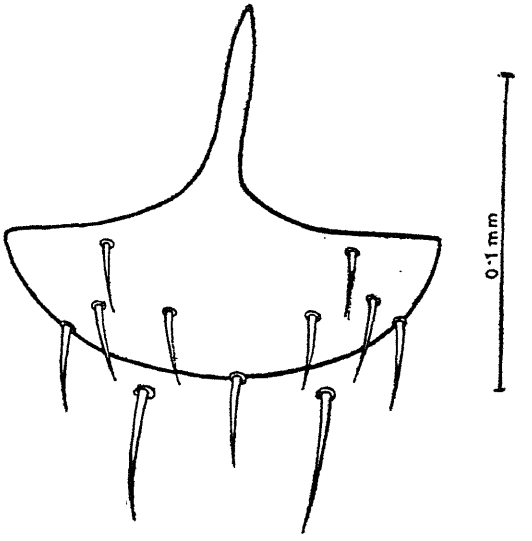

*Fig. 2. Upper and value. (*O. waterstoni*).

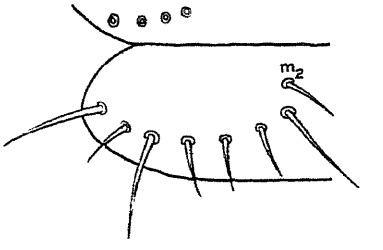

Fig. 3. Tergite of Th. I. (half). (*O. waterstoni*).

3. *O. caledonicus* Bagnall, 1935.

Body. Length excluding antenna about 1·60 mm.

P. A. O. With 39 cylindrical vesicles separated from each other.

Pseudocelli $\frac{44/023/34353}{1/000/00000}$

Legs. Unguis untoothed.

Anal spines. Slender, weakly curved and on distinct papillae.

Chaetotaxy :

I antennal segment. Ventrally with 5 equal sized setae forming a transverse row.

Dorsomedian part of Abd. II. Microseta F_2 constantly found anterior to F_1 and close to mediam pseudocelli only one seta S (Text-fig. 4).

Tergite of Abd. VI. As in text-fig. 5.

Ventral tube. As in *O. aurantiacus.*

All other characters as in *O. fimatus.*

After examining the holotype and a paratypic material there seems to be no doubt about the validity of this species.

4. *O. daviesi* Bagnall, 1935.

Examination of the specimen labelled as "Type" shows that although in many respects it is close to *O. caledonicus*, it can be separated by its 3 pseudocelli on the Abd. V tergite and the different arrangement of setae on the tergite of Abd. VI.

Body. Length excluding antenna about 1·53 mm.

P. A. O. With 31 cylindrical vesicles without basal lobules and not touching each other.

Pseudocelli $\frac{43/033/33353}{1/000/00000}$; each sub-coxa with one pseudocellous.

Legs. Unguis untoothed.

Anal spines. Fairly stout, curved and on distinct papilla.

Chaetotaxy :

I antennal segment : Ventrally as in *O. caledonicus*.

Dorsomedian part of Abd. II. As in *O. caledonicus*.

Tergite of Abd. VI. Microsetae *q* and *r* in front of anal spines of each side of median seta *P* converage with each other beyond hind margin of preceding segment (Text. fig. 6).

Upper anal valve. Obscure owing to specimen being mounted laterally.

All other characters agree well with *O. fimatus*.

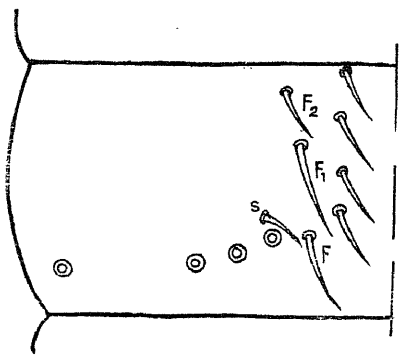

Fig 4. Dorsomedian part of Abd. II. (*O. calendonicus*).

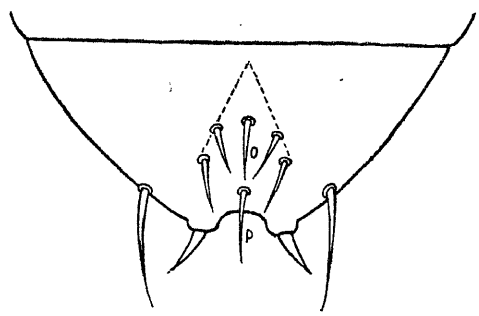

Fig. 5 Dorsomedian part of Abd. VI. (*O. calendonicus*).

With regard to *O. daviesi* Stach (1954) remarked, "between *O. daviesi* and *P. octopunctatus* Tullb. there exists in my opinion no difference". Nothing can be said definitely about the synonymy of *O. daviesi* with *O. octopunctatus* owing to the insufficiency of specimens of *O. daviesi* and lack of information about the ventral organ as both the specimens in the British Museum (Natural History) are females. However, in the present state of knowledge it can be inferred that *O. daviesi* belongs to the "armatus group" and seems to be a good species, as indicated before.

5. *O. moniezi* Bagnall, 1935

Syn. n. *O. evansi* Bagnall, 1935

This species as atonce recognised by the peculiar dome-like accessory sense clubs in the sense organ of Ant. org. III and in fact, Bagnall's original descriptions

of either *O. moniezi* or *O. evansi* bear very little resemblance to the species. The following description is based on the holotype of *O. evansi*.

Body. More or less cylindrical, cuticular granulation fairly fine, uniform and antennal bases unlimited. Length of body excluding antenna about 1·20 mm.

Antennae. Sense organ of Ant. III with 4 fairly granulated papillae, 5 setae, 2 long sense rods, 2 granulated sense clubs and 2 accessory dome-like sense clubs (Text-fig. 7). In length as long as anal spine.

P. A. O. With 13 ovoid vesicles with prominent secondary basal lobules as in *O. parthenogeneticus* Choudhuri, 1958.

Pseudocelli. $\frac{32/133/33333}{2/???/????}$; because of bad condition of the material, ventral pseudocelli of thoracic and abdominal segments obscure. Each subcoxa with one pseudocellus.

Legs : Unguis untoothed ; unguiculus with distinct granulated basal inner lamella and about 3 times shorter than unguis (Text-fig. 9).

Anal spines. Very slender, almost straight and on low papillae.

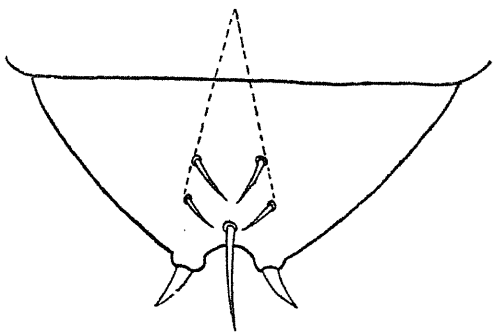

Fig. 6. Tergite of Abd. VI. (*O. daviesi*).

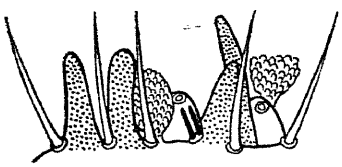

Fig. 7. Sense organ of Ant. III. (*O. moniezi*).

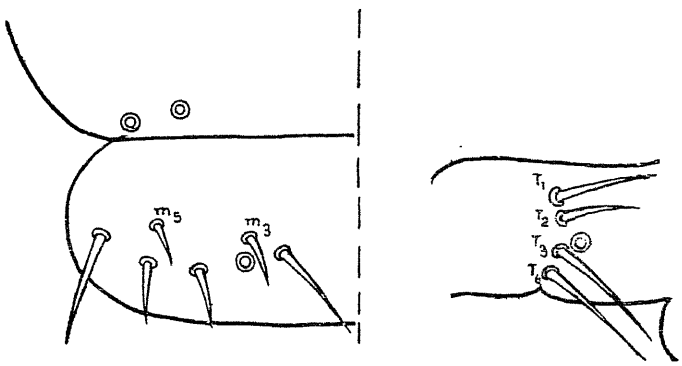

*Fig. 8. Claw of metathoracic leg. (*O. moniezi*).

Chaetotaxy :

Tergite of Th. I. Posterior half with 4 setae as in *O. parthenogeneticus* and anterior half with 2 setae m_3 and m_5 (Text-fig. 8).

Subcoxa I. With 4 setae T_6, T_3, T_2, and T_1 (Text-fig. 8), of them last two shorter than both T_3 and T_6.

Tergite of Abd. V. Middle part as in text-fig. 10.

Tergite of Abd. VI. Middle part as in text-fig. 10.

Upper anal valve. 5 setae on its upper surface as in *O. parthenogeneticus* but outer semicircular margin with 5 setae arranged as in *O. campatus.*

All other characters as in *O. parthenogeneticus.*

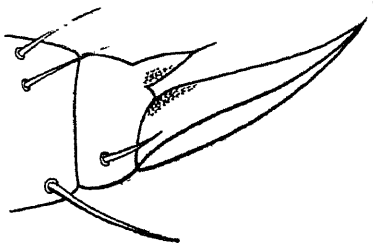

Fig. 9. Left half of tergite of Th. I. and left subcoxa I. (*O. moniezi*).

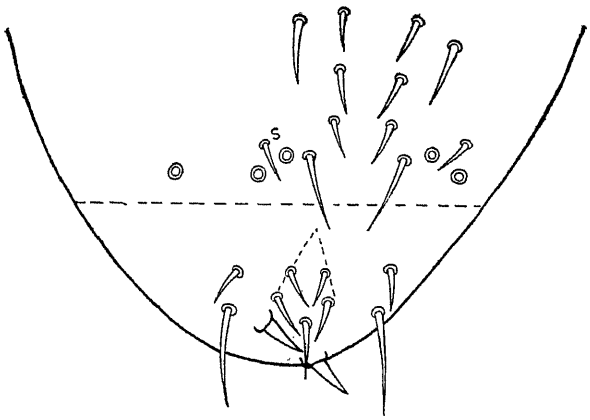

Fig. 10. Middle part of tergite of Abd. V and Abd. VI. (*O. moniezi*).

The difference between the holotype of *O. moniezi.* and that of *O. evansi* is accounted for by the fact that the type specimen of *O. moniezi* is an immature specimen as evident in (1) the very small size, (2) the absence of the genital aperture and (3) the chaetotaxy characteristic of the II instar of other species of the "armatus group". As the holotype of *O. moniezi* although an immature specimen clearly shows the characteristic dome-shaped accessory sense clubs in the Ant. org. III and agrees in pseudocelli with the holotype of *O. evansi*, the latter is considered as a synonym of *O. moniezi.*

6. *O. furciferus* (Börner, 1901).

Syn. n. *O. scoticus* Bagnall, 1935

O. celticus Bagnall, 1935

O. subequalis Bagnall, 1937.

This species has been accurately described by Stach (1954) and the British specimens, including the types and paratypes of *O. scoticus*, *O. celticus* and *O. subequalis*, agree with the Polish *O. furciferus.* The following discription is based on the British specimens.

Body. With third and fourth abdominal segments broader than others ; cuticular granulation fairly fine, with coarse granules dorsally on head, thus delimiting antennal base. Maximum length excluding antenna about 2·00 mm.

P. A. O. With 19–24 ovoid vesicles not touching each other.

Pseudocelli. $\frac{32/012/23233}{0/0\ 0/00000}$; each subcoxa with one or no pseudocellus.

Legs. Unguis with a distinct inner tooth ; unguiculus without basal lamella and almost as long as unguis (15 : 14).

Furca. Usually in the form described by Stach (1954) ; frequent variations found to occur as in text fiig. 11.

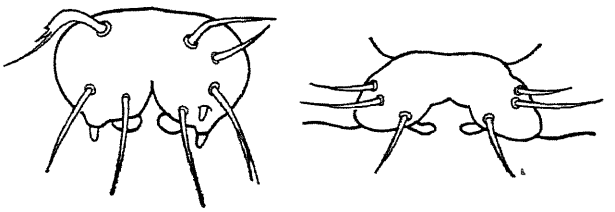

*Fig. 11. Furcal aberrations. (*O. furciferus*).

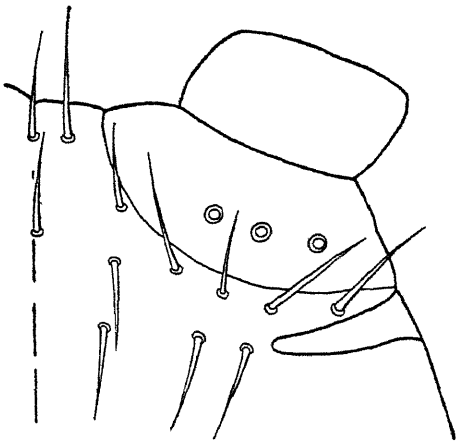

Fig. 12 Antero dorsal part of head. (*O. furciferus*).

Chaetotaxy :

Anterodorsal head. As in text-fig. 12.

Posterodorsal part of head. 4 setae P, P_1, P_3 and P_4 on each side, of which P and P_4 of almost equal size (Text-fig. 14).

Tergite of Abd. VI. Characteristic of this species having two setae *q* and *r* of both sides in a transverse line parallel to posterior margin of preceeding segment ; one median seta *p* in between anal spines and seta S in a position usual of many species of this group (Text-fig. 13).

Ventral tube. Basally 2 setae and no anterior seta.

All other characters correspond to those of *O. fimatus*.

The type specimen of *O. scoticus* has a furca which represents the intermediate form between the furca of *O. furciferus* and that of *O. auranticus*. But the holotype of *O. subequalis* and the paratypes of both *O. scoticus* and *O. celticus* display furca of the typical furciferus type. In view of the fact that the type specimen of *O. scoticus* agrees in all other respects with the paratypes of *O. scoticus* and thus with *O. furciferus* the present author has no hesitation in synonymising these species with *O. furciferus* redescribed by Stach (1954).

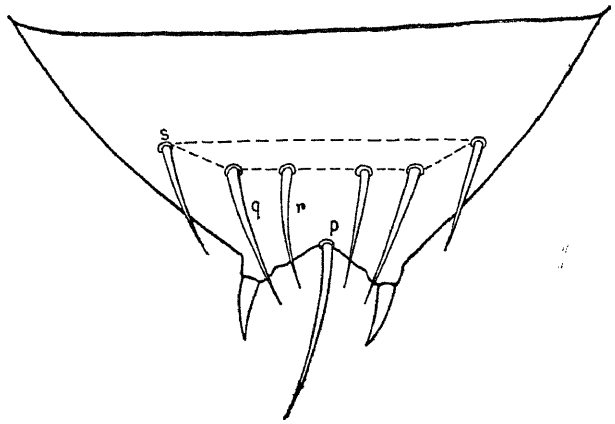

Fig. 13. Left half of posterodorsal part of the head. (*O. furciferus*).

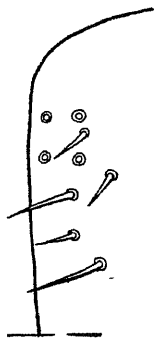

Fig. 14. Tergite of Abd. VI. (*O. furciferus*).

7. *O. halophilus* Bagnall, 1937.

The present writer has examined the holotype and two paratypes of this species and found that *O. halophilus* is a distinct species easily recognised by its very characteristic arrangement of pseudocelli on the posterodorsal part of head. Bagnall's original description is supplemented below.

Body. Almost cylindrical, tapering abruptly towards posterior end ; cuticular granulation fine, largest granules on head dorsally between two antennae thus delimiting antennal base. Length excluding antenna about 1·37 mm.

Antennae. .Sense organ in Ant. org. III with 5 finely granulated papillae, 4–5 setae, 2 fairly long thin sense rods and two finely granulated straight sense clubs.

P. A. O. With 24-30 ovoid vesicles with distinct basal lobules and separated from each other.

Pseudocelli. $\frac{44/233/44454}{2/000/11120}$; those of antennal base arranged in two groups and posterodorsal part of head with 4 pseudocelli arranged in a quadrangle (Text-fig. 15) ; subcoxae with 1–2 pseudocelli.

Leg. Unguis untoothed, unguiculus with granulated basal inner lamella and shorter than unguis (3 : 5).

Anal spines. Slender, straight and on low papillae.

Chaetotaxy :

Tergite of Th. I. Posterior half with 4–5 setae and anterior half with 1–3 variable number of setae, but seta corresponding to m_2 never present.

Subcoxa I. As in *O. moniezi.*

Tergite of Abd. VI. As in *O. caledonicus.*

Upper anal valve. As in *O. moniezi.*

All other characters agree with *O. parthenogeneticus.*

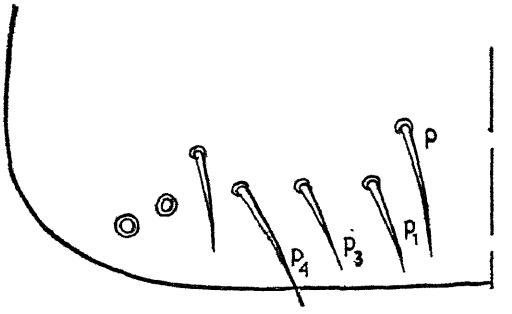

Fig. 15. Pseudocelli on left half of posterodorsal part of head. (*O. halophilus*).

8. *O. stachi anus* Bagnall, 1939.

Syn. n. *O. pseudostachianus* Gisin, 1956.

Body. More or less cylindrical ; cuticular granulation fairly coarse, coarser dorsally on head in between two antennae thus delimiting antennal base. Maximum length excluding antenna about 1·71 mm.

P. A. O. With 11–14 vesicles not touching each other.

Pseudocelli. $\frac{32/022/3335 \text{ or } 4\ 2 \text{ or } 3}{3/011/2111}$; each subcoxa with 2 pseudocelli.

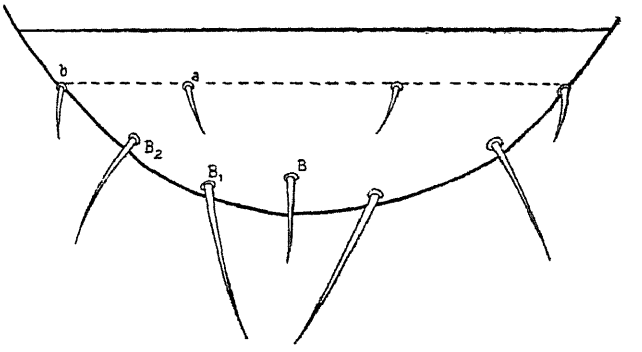

Fig. 16. Tergite of Abd. VI. (*O. stachianus*).

Chaetotaxy :

Subcoxa 1 : With 4 setae as in *O. moniezi.*

Tergite of Abd. VI. Charactertistic of this species, setae *a* and *b* almost of same size and on a transverse line about parallel to anterior margin of this segment, median seta B relatively smaller than either B_1 or B_2 and inserted almost on a line with B_1 of each side, the latter being largest seta (Text-fig. 16).

Ventral organ. 4 setae on both Abd. II and III sternites, these setae usually simple or forked (Text-fig. 17) in case of juveniles and fringed in adults. (Text-fig.17).

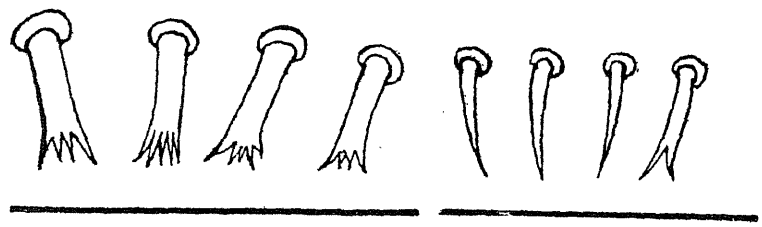

Fig. 17. Ventral organ. (*O. stachianus*).

Ventral tube. Neither basal nor anterior seta present, distally inner row with 4 setae but outer row with 1–3 setae.

All other characters as in *O. gotoi* Choudhuri, 1958.

Locality. (1) Soil in Hot house, Botanic Gardens, Cambridge, (2) Around roots of isolated clumps of grass and weeds at end of bacteria bed ; Wandle Valley (Joint Swerage Board Works), London, S. W. 19., England.

Gisin (1952) in describing *O. pseudostachianus* mentioned, "this is allied to *O. stachianus* from which it differs by 5+5 ps. oc. on abdomen IV (cf. 4+4) and 3+3 on abdomen V (cf. 2+2)". After examining many specimens of *O. stachianus* from this country and comparing them with some specimens of *O. pseudostachianus* sent by Dr. Gisin the author has no hesitation in concluding that they are Synonyms. The number of pseudocelli on the both of Abd. IV and V of this species is extramely variable. The setae of the ventral organ in the male of *O. stachianus*, which according to Denis (1938) are rod like and fringed at the tip do not prove to be constant. It has been observed that most of the large specimens have fringed setae where as the juveniles usually are with simple setae slightly modified from the other setae in the neighbourhood. Infact, such an aberration in the ventral organ has already been reported by Gisin (1952).

9. *O. pygmaeus* Bagnall, 1937.

On examining a paratype specimen possibly the only specimen of this species in the British Museum (Natural History) this is found to be a valid species but unfortunately bearing little resemblence to original description. As the same difficulty has been encountered in almost all the species described by Bagnall, it has been thought best not to ignore this specimen, simply because it is a paratype, but to redescribe it.

Body. Cylindrical, cuticular granulation extremely fine and uniform, antennal bases not delimited, length excluding antenna about 1·00 mm.

Antennae. Ant. org. III as in *imperfectus* (Denis, 1938).

P. A. O. With about 12 vesicles separated from each other.

Pseudocelli. $\frac{32/122/33342}{2/???/?????}$; pseudocelli of thoracic and abdominal sternite as well as subcoxa obscure owing to bad condition of material.

Legs. Unguis untoothed, unguiculus without distinct basal lamella and slightly shorter than unguis ; relative lengths of Un. III : Ung. III as 10·9.

Chaetotaxy :

Tergit of Th. I. 4 and 2 setae on the posteror and anterior half respectively.

Subcoxa I. As in *O. moniezi.*

Tergite of Abd. VI. As in *O. stachianus.*

Dorsomedian part of Abd. IV. On either side of posteromedian seta P 6 setae F, F_1, a, b, d and t_1 (Text–fig.18).

Ventral tube. As in *O. hortensis* Gisin.

Tergite of Abd. V. One median microseta in addition to 3 setae on each side of it. (Text–fig.19).

Upper anal valve. As in O. ugandensis Choudhuri, 1958.

All other characters are in agreement with *O. imperfectus.*

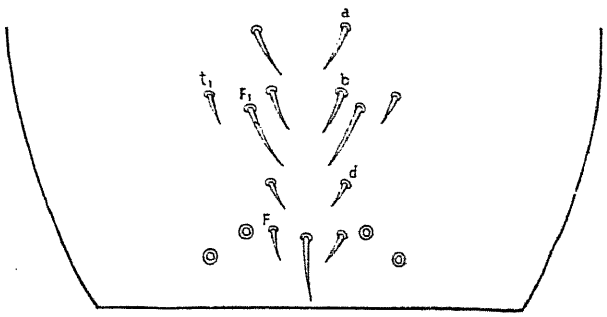

Fig. 18. Dorsomedian part of Abd. IV. (*O. pygmaeus*).

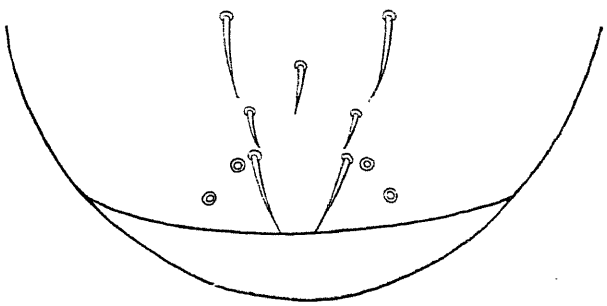

Fig. 19. Middle part of tergite of Abd. V. (*O. pygmaeus*).

Discussion :

Reference has already been made as to the highly variable characters employed by Bagnall, who has mainly used the colour of the body, number of vesicles in the post antennal organ, relative lengths and the distribution of

pseudocelli. After having devoted quite a long time on the systematics and the biology of many species of the genus *Onychiurus* it is felt that the first three characters should not be taken into consideration in a taxonomic work at least in the *Onychiurus*.

There are two possible groups of hypodermal pigments. One of them is merely byproducts of metabolism. Common pigments in nature are the carotenoids which are almost universal in plants. There is little doubt that these pigments are commonly absorbed by insects and accumulated in the blood or tissues, producing thereby a red or yellow colouration of the body. The author has experimentally found the partial dependance of colour on the nature of the food. In the experiment, debittered yeast mixed with natural carotene in the proportion of 20 : 1 was used as a food for about 50 insects of this group. After 25 days or so all of them assumed daffodil yellow colour which persisted even after a few successive moults.

Relative length of the body as a whole or any part of it greatly vary amongst the members of the same population ; between populations drawn from different habitats ; amongst the insect reared at different temperatures and also between the various juvenile forms of the same species.

Similarly, the number of the post-antennal vesicles varies a good deal not only from individual to individual but also from side to side of the same insect. Besides, the fundamental pattern undergoes variation since in the same species vesicles can be seen with or without lobules.

An analytical study of the variation in pseudocelli has proved that the arrangement of pseudocelli on the body except some parts such as the hind margin of head and the 5th abdominal tergits, rarely shows more than 10% variation which has been taken by the author as the maximum permissible level for a useful character, keeping in view that no two insects are exactly similar.

In this work great emphasis has been laid on the chaetotaxy as it on certain part of the body has proved to be of considerable taxonomic value owing to its relatively greater consistancy. It will be worth mentioning here that in lettering the setae Gisin's (1952) work has largely been followed.

Summary :

This is a part of the revision of Bagnall's work on the genus *Onychiurus*. Out of the sixteen species considered here, twelve were erected by Bagnall on characters the taxonomic value of which are questioned here. *O. flavidulus* Bagnall, *O. uliginatus* Gisin, *O. sublatus* Gisin, *O. evansi* Bagnall, *O. scoticus* Bagnall, *O. celticus* Bagnall, *O. subequalis* Bagnall and *O. pseudostachinus* Gisin are synonyms. The remaining eight *viz.* as *O. waterstoni* Bagnall, *O. caledonicus* Bagnall, *O. daviesi* Bagnall, *O. moniezi* Bagnall, *O. furciferus* Börner, *O. halophilus* Bagnall, *O. pygmaeus* Bagnall and *O. stachianus*, Bagnall are good speices.

Acknowledgments :

The author is deeply indebted to Prof. O. W. Richards, F. R. S. and Mr. H. E. Goto of Imperial College of Science and Technology, London for their esteemed criticisms and valuable suggestions. Thanks are due to Dr. T. Clay and the Trustees of the British Museum (Natural History) for giving me an access to the *Onychiurus* materials ; to Dr. H. Gisin of Geneva Museum for sending me useful informations along with some specimens and also to Dr. M. S. Mani, Zoological Survey of India for his help in the preparation of this manuscript.

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SOME NOTES ON *CHIRONOMUS PRIMITIVUS* MANI (DIPTERA) FROM THE SALT RANGE

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[Received on October 31, 1962]

Mani (1944) described *Chironomus primitivus* from a specimen collected by Sahni from Warchha salt mines, Salt Range, Punjab (now in Pakistan). In a later paper (1946) he also comprehensively dealt with other characters of evolutionary significance like the notal convexity, etc. While working on some Rock salt samples (exact localities not known) from the same area, I came across a more or less well preserved specimen of this species. The following notes form a supplement to the original description of the holotype. The specimen was mounted in Canada balsam (fig. 1). The plesiotype will be deposited in due course in the National collections of the Zoological Survey of India, Calcutta.

It agrees in the general characters with the holotype. Yellowish-brown in colour. Head slightly inclined forwards with large, reniform, dark-brown eyes. Ocelli wanting. Antennae yellowish-brown, broken, devoid of any hairs in the fossilized condition, but the presence of small papillae arranged in linear series indicate their existance. (Antennae were missing in the holotype). Labrum small ; palpi pale yellow and quadri-articulate as in holotype ; basal two segments in tact with the head, while the two apical ones broken and mounted on the same slide. Trophi dark-brown (fig. 2).

Pronotum very narrow ; mesonotum large, projecting forwards, followed by a short metanotum. Sutures not distinct. Wing crumpled. Haltere of one side seen. Only femora and tibia of the left middle and hind-legs seen in specimen. Tibia of former broken and mounted on same slide. Legs densely clothed with setae. Abdominal tergites compressed dorso-laterally and in excellant condition, while sternites not clear but, for minor traces.

From the excellantly preserved genitalia the specimen could be identified as male (fig. 3). In the holotype, they were not clear, although the specimen was assigned to be a male. The structure of the genitalia in general approaches those of the modern Chironomidae. The Aedeagus, paired parameres, claspette and styli (van Emden and Hennig, 1956) can be distinctly recognised. However, the suture separating the basi and dististyil is not seen, The right dististyli is broken a little at the tip. Parameres carry small setae on them.

Structural measurements (Length in mm)

1.	Head from the tip of the trophi to the occiput	0·32
2.	Eye	0·23
3.	Antenna	0·65
4.	Palpal segment I	0·026
	do II	0·032

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Fig. 1. *Chironomus primitivus* Mani (Entire) (Antennae, palpi and tibia of the middle leg re-constructed from broken pieces).

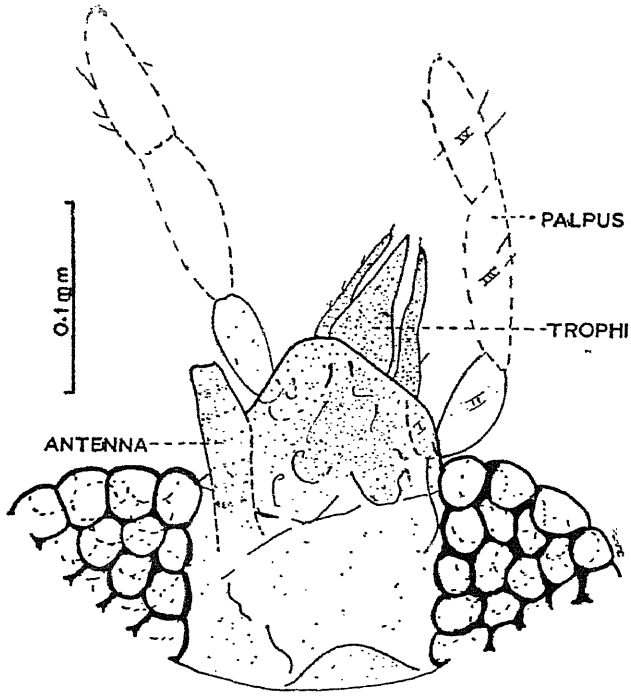

Fig. 2. Mouth parts (Ventral view) (= = = III & IV segments of the palpi re-constructed from broken pieces).

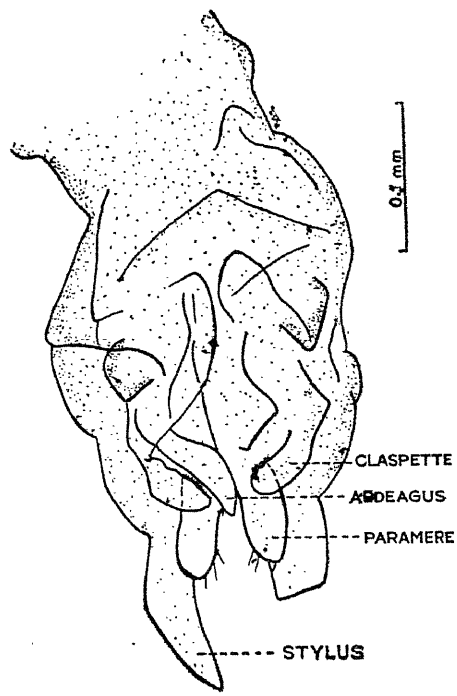

Fig. 3. Genitalia.

Palpal segment	III	...	...	...	0·088
do	IV	...	...	...	0·076
5. Trophi		...	...	...	0·044
6. Thorax		...	...	...	0·77
7. Tibia		...	...	...	0·33
8. Abdomen (from I to VIII abd. segment)			...	...	0·88
9. Genitalia					
Stylus	...	...	...	...	0·165
Paramere	...	...	...	...	0·075
Aedeagus	...	...	...	...	0·135
Claspette	...	...	...	...	0·135

Summary :

Mani (1944) described *Chironomus primitivus* from Saline Series from a single example. Recently, the author came across another well preserved example from the same series. Structures like antennae, genitalia, etc., which were lacking or not distinct in the holotype have been described in this paper.

Acnowledgment :

I thank Dr. Md. Qadiruddin Khan, Shri C. Krishnamoorthy, and Shri N. Raghava Rao, the successive Entomologists, Department of Agriculture, Andhra Pradesh, for evincing keen interest in my Research work on micro-fossils.

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MORPHOLOGY AND TAXONOMY OF THREE NEW SPECIES BELONGING TO THE SUBFAMILY *PROSOTOCINAE* YAMAGUTI–1958 (FAM. *LECITHODENDRIIDAE* : TREMTODA)

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[Received on April 20, 1961]

Introduction :

For the last eight months extensive studies have been carried out upon frogs of the species *Rana tigrina*, and a number of new species of trematodes of various genera have been discovered. In this paper 3 very interesting new species of the family *Lecithodendriidae* Odhner, 1910, subfamily *Prosotocinae* Yamaguti, 1958 have been described, and their relationships discussed. *Prosotocus poroformis* n. sp. is very interesting in the sense that it has got a genital sucker (=genital papilla, or gonotyl of the family *Heterophyidae* Odhner, 1914) as well as a distinct type of cirrus sac and peculiar position of its testes. *Prosotocus tigrinum* n.sp. closely resembles the other species of *Prosotocus* with asymmetrical vitelline glands (so far solely described from India), but has got peculiarities of genitalia and other morphological features. Whereas *Mehraorchis jainiformis* n.sp. (*Mehraorchis* Srivastava, 1934 is another purely Indian genus with the 4th species being described here) is considered of utmost importance due to the asymmetrical nature of its vitelline glands. The species *Prosotocus tigrinum* n.sp. is obtained in good numbers from a majority of the *Rana tigrina* frogs obtained from Bombay region. However, the other two species, *viz. Prosotocus poroformis* and *Mehraorchis jainiformis*, are extremely rarely found. For a fuller historical data for the species of *Prosotocus* the reader may refer to Murhar (1960).

The new species of *Mehraorchis* described here has been obtained from liver region, where they have been found along with other species of *Mehraorchis* either free in the bile ducts, and gall bladder (which gets enlarged and dicoloured), or in an encysted condition in the tissue of liver. Besides, *Mehraorchis ranarum* Srivastava, 1934 has also been obtained from the duodenal region of the intestine, and it has also been reported in an encysted condition from mesentry of the abdominal cavity of *R. cyanophlyctis* by Srivastava, (1934), and from the bile ducts and gall-bladder of *R. tigrina* by Bhalerao (1936). Tandon (1957) again obtained this parasite from liver of *R. tigrina*, and he has considered it another liverfluke. Whereas, this author does consider it a liverfluke, no pathogenic condition, externally apparent, could be noticed ; no doubt, a good deal of damage is observed in the liver and gall-bladder of the host. Therefore, it is well to consider *Mehraorchis* as a potential danger in the form of a liverfluke, even in the higher vertebrates, in due course. In this connection it may be further mentioned that Simha (1958) has already obtained *M. chamaeleonis* from gallb-ladder and bile ducts of a reptilian host *Chamaeleon zelanicus*.

For these studies more than 200 frogs were surveyed, and studies were made on live material, as well as on permanent preparations. Fixation was done in

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aqueous Bouin's fluid, and the whole mount specimens were kept in shape during fixation by giving them the most reasonable pressure of a coverslip. Stains like Mayer's Haemalum, Mayer's carmalum, Acid carmine, Ehrlich's haematoxylin were used.

Descriptions :

1. Prosotocus proformis n. sp. Body very small, a little wider posteriorly, pyriform, fully spinulated, 0·636 in length, width in shoulder region 0·475 and 0·57 in posterior region. Diameter of acetabulum 0·125, situated almost in middle of body, oral sucker ventroterminal, measuring 0·119×0·082, sucker ratio 5 : 8. Pharynx 0·0438×0·05, Oesophagus 0·05 in length, caeca wide apart, go below equatorial plane.

Testes 2, symmetrically situated, left one coming below cirrus sac, left testis measures 0·1125×0·1125, and right one 0·1250. Cirrus sac peculiar in shape, partly eclipsing acetabulum, becomes L-shaped, measures 0·0937×0·2875. Seminal vesicle has two loops instead of usual one ; parsprostatica swollen in middle, surrounded by prostatic glands; ejaculatory duct comparatively short. Male genital opening in common with female genital opening at base of a unique genital sucker or "gonotyl" like structure ; genital sucker at level of pharynx on left margin, measuring 0·10×0·0875.

Ovary elliptical and lying over right caecum ; ovary measuring 0·1125×0 056; receptaculum seminalis eclipsing the right margin of acetabulum. Vitellaria asymmetrically situated, spreading more on right side, some follicles occupying left side as well. Hindbody full of uterine coils, uterine coils full of small, elliptical, operculate, light-yellow eggs ; metraterm well developed and surrounded by gland cells, opening ultimately into genital papilla.

Excretory vesicle V-shaped, with arms of 'V' just reaching acetabular level. Excretory pore terminally situated, appears to be situated in slight depression of body.

Host : *R. tigrima* ; Habitate : duodenum ;

Locality : Western coastal region of India.

N. B. All measurements in this paper are given in milimeters.

2. Prosotocus tigrinum sp. n. Body quite small, ovall or pyriform, fully spinulated, measuring 1·275×0·65. Acetabulum equatorial and median, measures 0·1375×0·1250. Oral sucker ventroterminal, measuring 0·1312×0·1375. Sucker ratio 1 : 1. Pharynx 0·0625×0·050 ; Oesophagus 0·150 ; ceca unequal, wide apart extending upto posterior margin of acetabulum or a little beyond.

Testes ovate, asymmetrical, right testis more anterior, smaller and by the side of oesophagus ; left testis near left margin and slightly lower in level and bigger ; right and left testes measure 0·1625 ×0·1375 and 0·150×0·20 respectively. Cirrus sac retort-shaped, just touching caecum of left side ; measures 0·375×0·150. Vesicula seminalis lies in one simple loop in first half of cirrus-sac ; persprostatica lying after siminal vesicle, rounded and vesicular in its middle, surrounded by prostatic glands which open by fine ducts into wall of prostatic vesicle ; ductus ejaculatories rather short, distinct cirrus present. Male genital opening distinct, separte, and on left margin and at level of anterior margin of left testis.

Ovary single, on right of acetabulum, ovate, smaller than both testes, completely intracecal in field between right caecum and acetabulum, measuring 0·1375 ×0·10. Receptaculum seminalis distinctly on right lower margin of acetabulum ;

a small laurer's canal visible, opening of laurer's canal not clear. Uterine coils not many ; coils of descending loop, short median transverse limb, and on left side coils of ascending loop found, latter shooting up straight, running into metraterm. Metraterm opening into distinctly separate, ventrally situated, female genital aperture. Female genital apperture surrounded by arrangement of muscles forming sphinctral opening, and ray-like lines surrounded this opening, obviously well regulated opening. Vitellaria completely asymmetrically situated, towards field right of oesophagus, a few follicles lying over oesophagus and pharynx. Generally, only one common vitelline duct present.

Excretory vesicle V-shaped with typical limbs reaching upto level of acetabulum ; excretory pore terminal or a ventroterminal.

Host : *R. tigrina* ; Habital—duodenum.

Locality : Western coastal region of India.

3. Mehraorchis jainiformis n. sp.—Body elongately elliptical, flat, moderately, delicate, entirely spinulate, spines slightly denser in anterior body region, small sized worms, maximum width in acetabular region, measures $4{\cdot}03 \times 1{\cdot}84$. Acetabulum little pre-equatorian and round, 0·28 in diameter. Oral sucker ventrally disposed and terminal, measuring $0{\cdot}40 \times 0{\cdot}30$ hence oral sucker much larger than ventral sucker. Prepharynx follows oral sucker, 0·20 in length, well developed pharynx present, bulbous in shape ; 0·16 in diameter ; oesophagus qu.te long, 0·56 in length ; intestinal ceca run parallel and stop short of posterior end, or extend a little more, thus variable character.

Testes massive, somewhat asymmetrical, ovoidly rounded with smooth margin ; right testis larger and situated more anterior than left one, left testis situated behind cirrus sac, right and left testes measure, $0{\cdot}30 \times 0{\cdot}64$ and $0{\cdot}76 \times 0{\cdot}52$ respecvively ; vaseferens of left side shorter than that of right side, vas deferens very small. Cirrus cac extracecal, left side ; vesicula seminalis with single coil : parasprostatic prominent, spindle shaped, surrounded by prostatic glands which concentrate towards middle region, parsprostatica 0·36 in length. Prominent and protrusible cirrus present, which opens in distinct genital atrium, on left margin very near oral sucker.

Ovary much smaller than testes, lying on right side of acetabulum, not overlapping but contiguous to acetabulum, smoothly ovate in form, and intracecal, measuring $0{\cdot}52 \times 0{\cdot}40$. Entire hindbody full of uterine coils which extend right upto posterior extremity, descending loops lie on right and ascending loops on left, ultimately a straight utertine canal forms into metraterm which opens into common genital atrium. Eggs operculate, small, elliptical, yellowish in life, measure $0{\cdot}0375 \times 0{\cdot}0187$. Vitelline follicles on right side only, overlap right testes and ovary, starting from pharyngeal field and below pharynx cover oesophagus and extend upto a little below equatorial plane ; single duct emerges from middle of follicles which joins oviduct, oviduct also joined by duct of receptaculum seminalis which lies posterior to acetabulum.

Excretory bladder Y-shaped, with very short median limb and long anterior cornu ; excretory pore ventroterminal.

Host : *R. tigrina* ; Habitat—bile ducts and liver.

Locality : Western coastal region of India.

Discussion :

Short discussions are given here for each species separately in order to illustrate the features which justify their recognition as separate species ; and in the

last paragraph a general discussion is also given in order to discuss the greater evolutionary significance of the new species. These points are in addition to what has already been pointed out in the "Introduction".

Prosotocus poroformis n. sp. thanks to its asymmetrical vitelline gland definitely falls in line with the four species of an Indian type of *Prosotocus* described by Pande (1937), Kaw (1943 and 1950) and Murhar (1960). It resembles the European type of the species of *Prosotocus* (species with symmetrical vitelline gland, along with other peculiarities) mainly in the symmetrical nature of its testes—in which feature it differs from the species of *Prosotocus* with the asymmetrical vitellaria – and a few vitelline follicles have definitely come on the left side as well. But it is different from all the species hitherto described under the genus *Prosotocus* Loas, 1899 in having a conspicuous genital sucker or genital papilla, with the genital pore being much more preacetabular. It possesses a peculiar type of vesicula seminalis, as well as a massive cirrus sac. The pretesticular nature of the cirrus sac is a feature homologous to *Mehroarchis* another purely Indian genus of the subfamily *Prosotocinae* Yamaguti, 1958. Furthermore, it resembles *Prosotocus himalayi* Pande, 1937 only in the position of its ovary and the extent of the intestinal ceca. Besides, there are other differences in the various measurements. On the whole, the author feels amply justified in describing *P. poroformis* as a new species.

Prosotocus tigrina n. sp. mainly resembles only the Indian type of Prosotocus, *viz*,, *P. himalayi* Pande, 1937, *P. kashabia* Kaw, 1943, *P. pratapus* 1950, and *P. dorsoporus* Murhar, 1960, in having an asymmetrical vitallaria, and testes. The features which distinguish this species from all these species are : a clearly intracecal ovary, which eclipses no other organ and is acetabular in position ; a separate, ventral and peculiar, female genital opening ; an extracecal cirrus sac ; the presence of a prepharynx and a ventroterminal oral sucker, which is equal in size to the acetabulum. It can be easily differentiated from *P. himalayi* in the position and size of its ovary, and the extent of its ceca, as well as, some more features. It differs from *P. pratapus*, along with some more feature, mainly in not having that type of genital pore, and its cirrus pouch does not at all touch the acetabulum, as well as the position of its ovary. It can also be distinguished from *P. kashabia*, due to the position of its ovary, its uterus not being so limited in size, its cirrus sac not becoming intracecal, the nature of the genital openings, and some more features as well. Finally, *P. doroporus* can also be distinguished from *P. tigrina* n. sp., for, the new species does not have a dorsally situated and a so much anterior genital opening ; the cirrus sac of the new species differs in shape ; the disposition of testes and the ovary is peculiar to the new form ; in the new form the oral sucker is not subterminal ; and finally, the other morphological features may also be taken up to distingush this from *P. dorsoporus*. Hence there is every reason to hold *P. tigrinum* n. sp. as valid.

A key to all the species of Prosotocus hitherto described, including another European form *P. mirabilis* Grabda, 1959, not included in Murhar's (1960) key has been given. The order of the species in this key also speaks to some extent the relationships and affinities of the species included therein :

Key to the species of Prosotocus Looss, 1899

1. Vitelline gland present on both sides.....2
   Vitelline gland present on right side only.....5
2. Genital pore posttesticular ; ovary entire.....A, B

Genital pore posttesticular ; ovary lobed....*P. vespertilionis*.....
Modlinger, 1930.

A. Genital pore fully marginal, body covered with spines.. .....
P. fuelleborni Travassors 1930.

B. Genital pore not fully - marginal, boby covered with papillae.....
P. sigalasi Bailenger et.....
Chanseau, 1954.

Genital pore testicular or slightly pretesticular.....3

3. Ovary median, cirrus sac postacetabular to preacetabular.....
..... *P. confusus* Looss, 1894.
Ovary lateral ; cirrus sac preacetabular.....4
4. Genital pore testicular ; ovary and testes more or less equal in size.....
.....*P. indicus* Mehra, 1928.
Genital pore pretesticular.. .....A and B
A Ovary much smaller than testes.....*P. infrequentum* Srivstava, 1933.
B. The transverse uterine loop lacking ; cirrus sac in front of the ventral sucker..... .....*P. mirabilis* Grabda, 1959.
5. Genital pore testicular.....5
Genital pore pretesticular.....7
6. Uterus with few coils ; ovary preacetabular ; cirrus sac enters intracecal field.... .....*P. kashabia* Kaw, 1943.
Uterus with more extensive coils ; ovary acetabular and fully intracecal ; cirrus sac remains extratecal..... ..... *P. tigrinum* n. sp.
7. Genital pore opening on dorsal surface.....*P. dorsoporus* Murhar, 1960.
Genital pore opening on ventral surface only..... 8
8. Genital pore with a genital sucker or papilla ; left testis blow cirrus sac.
.....*P. poroformis* n. sp.
Genital pore without a genital sucker or papilla ; left testis above cirrus sac.....9
9. Ovary larger than testes, longer intestinal ceca, and body
.....*P. himalayi* Pande, 1937.
Ovary smaller than right testis ; intestinal ceca and body not so long.
.....*P. pratapus* Kaw, 1950.

Finally, *Mehraorchis jainiformis* n. sp. is the fourth species of a purely Indian genus. Its most essential character is the presence of vitelline follicles only on right side, thus making this feature of the new species homologous to the "Indian" species of *Prosotocus* discussed above. Other distinguishing features are : the presence of a well developed prepharynx ; an extensive uterus ; an ovary, not eclipsing the acetabulum—as it has happened in the three species of *Mehraorchis* already described—largest size of eggs. On comparison of the other morphological features, it is found to come nearer to *M. ranarum* Srivastava, 1943 and *M. Charmaeleonii* Sinha, 1958. It differs from *M. tigrinum* Gupta, 1954 in the size and position of its ventral sucker, which is here smaller than oral sucker. In *M. tigrinum* another peculiarity pointed out by Gupta (1954) is the extension of uterine coils beyond the endings of the intestinal caeca. But, it may be pointed out here that this is an undependable character, as the extent of the caecal endings, and the uterine coils also, has been found to be fluctuating, and sometimes it has been found that the ceca have extended themselves so much so that almost no posterior field is left. On the whole it has been found fully logical to uphold the suggestion of a new species, *viz.*, *M. jainiformis* in this paper.

Plates I, II and III have been prepared to scale with the help of camera lucida.

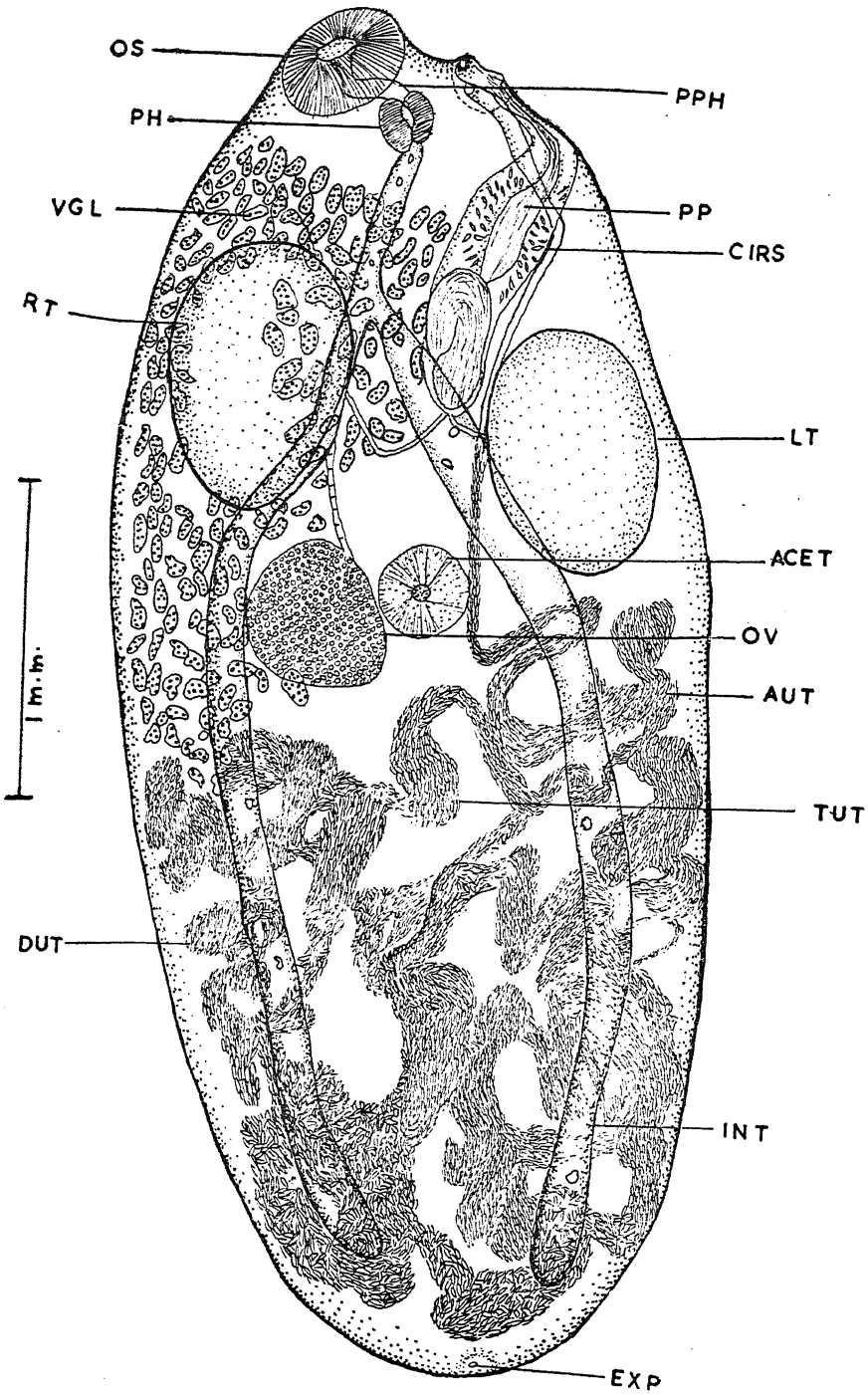

Plate I—*Mehraorchis jainiformis* (dorsal view).

A key to the species of *Mehraorchis* Srivastava, 1934 is being given below :

1. Vitelline follicles present on both sides, prepharynx absent 2
   Vitelline follicles present on one side only ; distinct prepharynx present .... *M. jainiformis* n. sp.....
2. Suckers subequal..... 3
   Acetabulum distinctly larger than oral sucker..... ..... *M. tigrinum* Gupta, 1954.
3. Cirrus-sac short ; ends of ceca dilated..... .... *M. ranarum* Srivastava, 1934.
   Cirrus-sac longer ; ends of ceca not dilated..... .... *M. chamaeleonis* Simha, 1958.

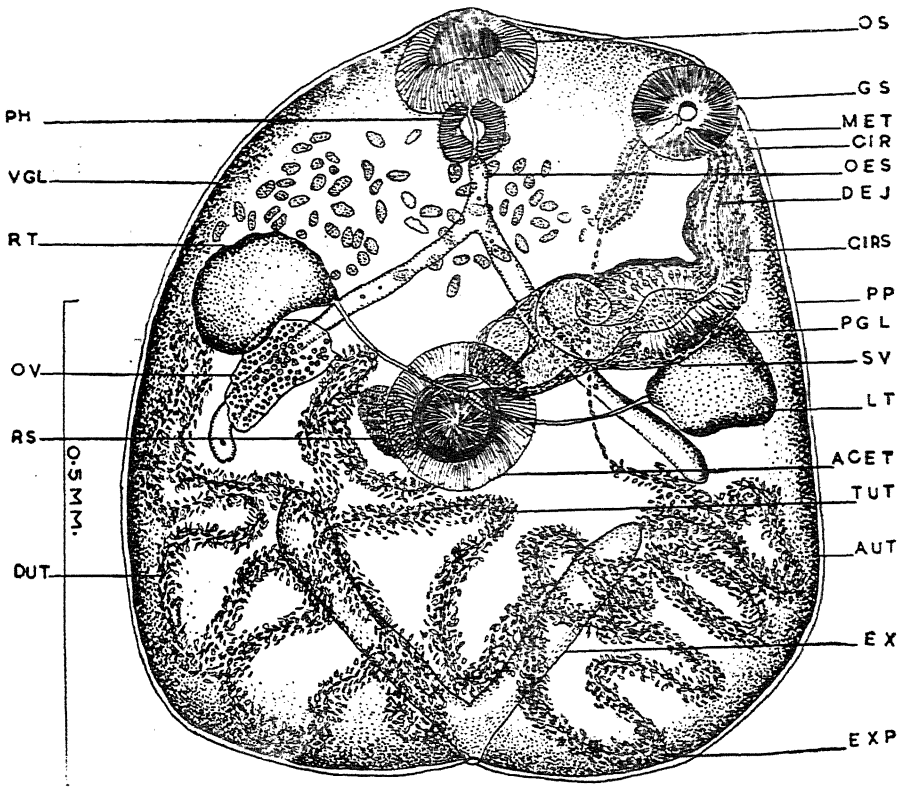

Plate II—*Prosotocus poroformis* (Ventral view).

ABBREVIATIONS

ACET—acetabulum ; AUT—ascending uterine coils ; CIRS—cirrus sac ; CIR—cirrus ; DEJ—ductus ejaculatorius ; DUT—descending uterine coils ; EX—excretory vesicle, EXP—excretory pore ; GS— genital sucker ; LT—left testis ; MET—metraterm ; OV—Ovary ; OES—oesophagus ; OS—oral sucker ; PH—pharynx ; PPH—prepharynx ; PP—parsprostatica ; PGL—prostatic glands ; RT—right testis, RS—receptaculum seminalis ; SV—vesicula seminalis ; TUT—transverse—uterine coil ; YGL—vitelline gland.

The absence of vitelline follicles from the left side in *Mehraorchis jainiformis* n. sp. is quite unique, as it is a character homologous to those Indian species of *Prosotocus* which also do not possess a symmetrical vitellaria on their left side These are the two genera which have been correctly included by Yamaguti (1958) in the subfamily *Prosotocinae* Yamaguti, 1958. Obviously, some evolutionary relationships do exist between these two genera. *Mehraorchis jainiformis* n. sp. might have been divergently evolved from the same type of ancestral prosotocid which gave rise to those forms of *Prosotocus* which have an asymmetrical vitellaria, or this character may be only a later acquisition, and it is quite significant to note that such forms have been reported in this part of the earth, from such regions which are Zoolographically quite akin. At the same time it appears that these species of *Prosotocus* are more highly evolved than the species of *Mehraorchis*. *M. jainiformis* appears to be more recent than the other 3 species of *Mehraorchis* hitherto described, *viz.*, the species with symmetrical vitelline glands. Furthermore, it is evident that the major difference between the two genera is the length of intestinal caeca. In the case of the species of *Prosotocus* the caeca appear to have been reduced, from one fourth to half of the length of caeca of *Mehraorchis*. Hence, without doubt, the two genera are quite closely related ; and this fact should be further borne out by the studies of the life histories of these forms, which hitherto, are completely lacking. Ecologically speaking, as has been already stated, *Mehraorchis* definitely proves to be more adventurous than *Prosotocus*, though here too most close relationships exists between the two.

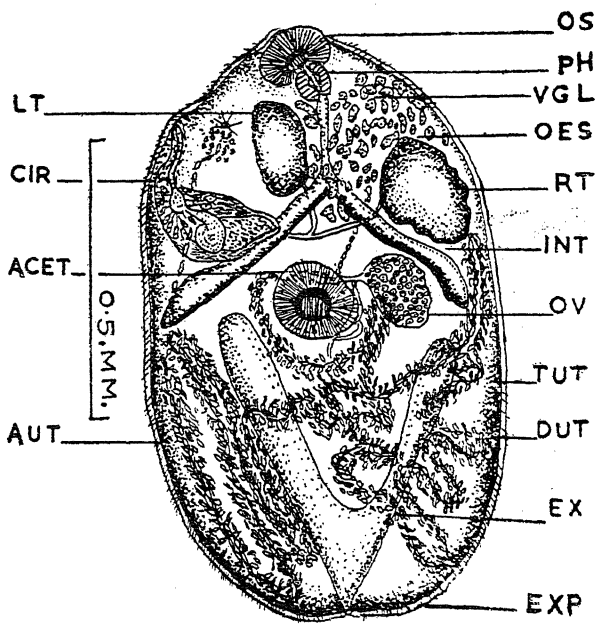

Plate III—*Prosotocus tigrinum* (dorsal view).

Another point of general interest is the occurrence of a genital sucker only in *Prosotocus poroformis* n. sp. of all the members of the subfamily *Prosotocinae*. Such a distinguishing feature has also been found by Hall (1960) in *Neoprosthodendrium*

progeneticum n.g., n. sp., although the genital papilla in Hall's species is not so big, possibly due the age of the worm. According to Cable (personal communication, 1960) this feature is not very "surprising", as it could often be found more especially in those forms which do not possess a cirrus sac ; although in the case of *Prosotocus poroformis* a well-developed cirrus sac is present. A gonotyl or a genital sucker, appears to the author, to be merely of some adaptive significance to the worm ; and a really correct assessment could be made about its anatomical value and evolution by a careful study of the ecological and anatomical conditions of all the related worms which have succeeded in acquiring a genital papilla or a genital sucker.

Acknowledgements :

This study was supported by a Research Training Scholarship from the Ministry of Scientific Researeh and Cultural Affairs, Govt. of India. The author wishes to express his gratitude to his supervisors Dr. R N. Singh, Head of the Zoology Department, M. M. V., Jabalpur, as also to Dr. G. P. Jain, for their unreserved advice and help for carrying out this work. The author is indebted to late Prof. U. D. Mukerjee, Principal, M. M. V., Jabalpur. for providing me with the necessary support and encouragement, and to the officials of the University of Jabalpur for their generous assistance. Thanks are also due to Dr. R. M· Cable for his suggestions, and Dr. J. E. Hall for providing me with his learned reprints.

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EFFECT OF GRAZING ON THE GENERAL HERBAGE OF BANARAS HINDU UNIVERSITY GROUNDS AND A STUDY OF SEED CHARACTER AND REPRODUCTIVE CAPACITY OF FOUR WEEDS

By

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[Received on January 25, 1961]

The grazing grounds within the campus of Banaras Hindu University are grouped for this study into three types, *viz*, (1) protected grounds, (2) medium-grazed grounds and (3) overgrazed grounds. Representative areas of each are charted to examine the spatial relations of the forbs and associated grasses. The frequency distribution of the species is given in table 1. The frequency distribution was noted by random sampling method by taking 90 quadrats of 1 sq. metre area per field.

TABLE 1

Percentage frequency distribution of grasses and forbs during the summer (May, 1959).

Species	Protected plot	Medium-grazed plot	Over grazed plot	Remarks
Alysicarpus monilifer DC.	**35**	**35**	**60**	Increaser
Argemone mexicana L.	**0**	**0**	**3**	Indicator
Blumea lacera DC.	40	25	30	
Boerhaavia diffusa L.	**25**	**40**	**53**	Increaser
Cassia tora L.	0	0	5	
Convolvulus pluricaulis L.	**80**	**60**	**83**	Neutral
Crotalaria medicogenia Lamk.	20	10	0	
Croton sparsiflorus Morung.	**30**	**0**	**70**	Increaser
Cynodon dactylon Pers.	**50**	**83**	**85**	Increaser
Desmodium triflorum DC.	**70**	**70**	**43**	Decreaser
Desmostachya bipinnata Stapf.	25	0	13	
Dichanthium annulatum Stapf.	**100**	**100**	**76**	Decreaser
Eclipta alba Hassak.	0	0	6	
Euphorbia hirta L.	35	30	30	
Euphorbia thymifolia L.	30	20	43	
Evolvulus alsinoides L.	**40**	**60**	**80**	Increaser

Species	Protected plot	Medium-grazed plot	Over grazed plot	Remarks
Evolvulus nummularius L.	**45**	**60**	**90**	Increaser
Heliotropium strigosum Willd.	**10**	**20**	**75**	Increaser
Heylandia latebrosa DC.	20	35	10	
Indigofera linifolia L.	**65**	**80**	**37**	Increaser
Indigofera ennaepyhlla L.	5	10	3	
Imperata spp.	5	0	0	
Justicia simplex Don.	0	3	3	
Launea spp	15	10	17	
Mollugo hirta Thumb.	0	0	6	
Orthosiphon pallidus Royle.	10	15	3	
Portulaca oleracea L.	0	0	3	
Rungia parviflora Nees.	0	10	6	
Scoparia dulcis L.	25	10	6	
Sida spp.	10	20	0	
Solanum xanthocarpum Shrend & Wendl	0	0	3	
Spheranthus indicus Linn.	0	0	3	
Tephrosia purpurea Pers.	10	5	3	
Trichodesma indicum R.Br.	5	15	13	
Vernonia cinera Less.	**67**	**85**	**75**	Increaser
Volutarella divaricata Benth.	**5**	**20**	**6**	Indicator
Ziziphus spp.	**0**	**0**	**3**	Indicator

As a result of heavy precipitation during the months of July and August one finds tremendous growth of grass and recurring population of forbs. The dry conditions of the soil sets in September and approaches its peak in the month of May and June.

Dichanthium annulatum is the dominant grass of the grazing fields with forbs population of varying intensities. The species show progression and retrogression of their respective population according to the periods of the seasons or 'ritus'.

A close examination of chart quadrats and frequency data of the grazing grounds reveals four catagories of species *viz.*, "increasers", "decreasers", "neutrals" and "indicators" of grazing. The ecological behaviour of each type together with a study of their seed character and reproductive capacity is given. *Evolvulus alsinoides* and *E. nummularius* increases in their populations, *Indigofera linifolia* decreases in its frequency occurrence and *Convolvulus pluricaulus* remains neutral to grazing being equally well of in both protected and overgrazed plots.

Habit, habitat and morphology :

1. *Evolvulus alsinoides.*—It has a rosette type of habit at times, but is commonly a small prostrate weed. Flowers are arranged in axillary solitary cymes, which are blue in colour, being showy for insect visitors. Fruits are dehiscent capsules often discharging oval seeds whose colour ranges from dark reddish brown to light yellow.

2. *Evolvulus nummularius.*—It is prostrate much branched, perennial herb. Its habit in the disturbed fields and foot paths shows a compact dense growth with small leaves. However, near margins of drains the growth is laxuriant with large leaves. Flowers are axillary in few-fid cymes.

3. *Indigofera linifolia.*—It is a small prostrate perennial herb ; some times erect in protected and medium grazed fields. It is less frequent or even absent in some of the overgrazed fields during the summer season. Flowers are bright red, typically papilionaceous.

4. *Convolvulus pluricaulis.*—It is a diffused spreading, hairy, perennial herb. It is distributed in all the types of fields and along the road sides. Maximum spread of branches was observed in protected fields. Flowers are quite prominent, axillary and white. Fruit is a capsule, less than 4·23 cm. diameter which 1 or 2 globose, dark coloured seeds.

Seed characters and reproductive capacity :

The technique suggested by Salisbury (1942), is followed for estimating seed character and reproductive capacity. Soon after collection from the field the seeds are properly packed, labelled and stored. The germination of seeds is tried in between moist filter papers placed in petri dishes at room temperature, for one month.

Evolvulus alsinoides.—Plants collected from the overgrazed area show greater weight coupled with less number of seeds per plant. The seeds are minute and their number varies from 2 to 4, and at times only one per capsule. The seed output is 334 in protected areas which is reduced to 2 4 in overgrazed areas (see table 2). Germination counts of seeds collected from overgrazed areas show a high percentage when compared with those of medium-grazed and protected plots.

Evolvulus nummularius.—The plant bears dehiscent capsules each containing 2 or 4 reddish or brownish seeds. The seeds are heavy and the seed output is low being 118 in overgrazed and 175 in protected fields. When compared with *E. alsinoides* it has a high frequency distribution of 90% in the overgrazed fields. However, this adaptation is neutralised by the low seed output (see table 2).

Indigofera linifolia.—The ptant bears globose pods each containing a single rounded mucronate seed. The seeds are coloured yellow or brown with minute black dots. The population of *Indigofera linifolia* shows declines in response to grazing and this coupled with low seed output is disadvantageous for the weed to spread in the grazing grounds.

Convolvulus pluricaulis.—This weed produces comparatively heavy seeds in protected as well as overgrazed areas compared with the other three weeds presented earlier. Further, it is equipped with higher germination counts of seeds in all the habitals. Thus it counteracts grazing effects by virtue of its propagules.

TABLE 2

Seed characters and reproductive capacity of four weeds in areas open or protected to grazing

Characters studied	Plants											
	Evolvulus alsinoides			Evolvulus nummularius			Convolvulus pluricaulis			Indigofera linifolia		
	*A	*B	*C	*A	*B	*C	*A	*B	*C	*A	*B	*C
Seed colour	Dark reddish brown to light yellow			Reddish or brownish or whitish yellow			Dark black			Yellow or brown with black dots		
Seed dimension :												
Length in μ	1619	1585	1631	1892	1859	1758	1959	1751	1878	1364	1542	1401
Breadth in μ	1196	1097	1552	1233	1313	1207	1191	1019	1224	1300	1416	1174
Average seed weight in mg.	0·66	1·01	1·34	1·69	16·8	16·3	12·2	1·4	14 0	1·7	1·61	1·28
Average seed output	333	412	224	175	148	118	2224	436	370	495	271	150
Average germination %	16	12	21	39	29	26	34	27	31	29	12	28
Average reproductive capacity	53	49	47	68	43	31	756	117	115	45	33	32

*A = Protected field.
*B = Medium-grazed field.
*C = Overgrazed field.

Discussion :

A marked seasonal periodicity in temperature and moisture conditions produces a series of fluctuating habitats in different seasons. The plant growth is luxuriant during the rainy season when both temperature and moisture are at the optium. The vegetation declines rapidly in the following cold season on account of lower temperature, drying soil and increased biotic activities.

During the summer the general vegetation suffers from desiccation and grazing. The grazing becomes more acute as the productivity and availability of vegetation become scarce. Even this thin and spares vegetation is scraped for the feeding of animals.

The 'Vasant ritu' as described by Misra (1959), is a period of intensive phenological activity. Longer photoperiods, rising temperature and diurnal fluctuations bring about foliation and floration. The local weed flora pass through short cycles of flower initiation and fruit development. Hence during the summer (May, 1959) the records for frequency distribution, seed character, and reproductive

capacity were made to bring out the contrasts in the protected, medium-grazed, and overgrazed fields on account of grazing.

Kucera (1956) indicated grazing and trampling by live stock as the paramount factors in the increase or decrease of grassland species. Weaver and Hansen (1941) describe the process of degeneration of grasslands under grazing by observing the behaviour of species as (1) "increasers", (2) "decreasers" and (3) "invaders".

In the present study *Evolvulus alsinoides* and *E. nummularius* show progression in their population as a result of heavy grazing while *Indigofera linifolia* declines. *Convolvulus pluricaulis* does not respond to grazing as there is no change in its frequency, (*i.e.*, it is neutral). Invasion following grazing account for indicator species such as *Argemone mexicana* L. and *Ziziphus* spp.

The habit of the four weed shows distinct morphological plasticity in the three different fields. The general form assumed ranges from compact prostrate in overgrazed to loose prostrate and sub erect forms in protected and medium-grazed fields.

The seeds of *Evolvulus alsinoides* and *E. nummularius* collected from the over-grazed areas are heavier being 1·34 mg. and 16·0 mg., respectively, as compared to those of protected and medium-grazed fields which are 0·66 mg. 1·69 mg., respectively. On the other hand seed weight of *Indigofera linifolia* in protected fields is higher, being 1·7 mg., as compared to that of medium-grazed and overgrazed, being 1·61 mg. and 1·28 mg., respectively. *Convolvulus pluricaulis* produces comparatively heavy seeds in protected as well as in overgrazed areas ; the weight being 12·2 mg. and 14·0 mg., respectively.

The seed output of *Evolvulus alsinoides* and *E. nummularius* in protected field is 334 and 175, respectively, which is reduced to 224 and 118 in overgrazed fields. *Indigofera linifolia* seems to suffer from grazing the most. Its seed output goes down from 495 in protected fields to 150 in the overgrazed fields. As has already been shown populations of *Indigofera linifolia* show decline in response to grazing.

The seed output is highest in the case of *Convolvulus pluricaulis*, *i.e.*, 2224 in the protected fields. But in this case also grazing affects the seed output *i.e.*, it is reduced to 370 in overgrazed field.

The percentage germination of seeds of *Evolvulus alsinoides* collected from over-grazed field is higher than of those from protected and medium-grazed fields. But in the other three species the relationship of germination to grazing is just the reverse.

Reproductive capacity of species according to Salisbury (1942) is as much characteristic as any other specific feature and one moreover of the greatest ecological importance. The present study reveals that its magnitude is significantly reduced by the factor of grazing in all the species.

Summary :

Grazing as on ecological factor, influences the spread and growth of species. Four herbs, *viz.*, (1) *Evolvulus alsinoides*, (2) *Evolvulus nummularius*, (3) *Indigofera linifolia* and (4) *Convolvulus pluricaulis* have been examined,

They show distinctive distribution in protected, medium and overgrazed fields of Banaras Hindu University campus. Both the species of *Evolvulus* show progression in their populations as a result of heavy grazing, while *Indigofera linifolia* declines. *Convolvulus pluricaulis* does not respond to grazing (*i e.*, it is neutral).

The biological equipment of the herbs versus grazing in terms of seed output, and reproductive capacity has been estimated.

Acknowledgement :

The author welcomes this opportunity to express his deep indebtedness and warmest thanks to Dr. R. Misra, F. N. I., for valuable guidance and suggestions. Thanks are also due to the Government of India for providing the author with financial assistance in the form of Research Scholarship.

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REVISION OF FELLODISTOMOIDEA (SYN. FELLODISTOMATOIDEA LA RUE, 1957): FAMILIES FELLODISTOMIDAE WOODCOCK, 1912, GYMNOPHALLIDAE DOLLFUS, 1939 AND MONODHELMINTHIDAE DOLLFUS, 1937

By

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[Received on August 9, 1962]

The systematic position of Gymnophallidae has been differently held by various authors. Yamaguti (1958) includes it as a subfamily under Microphallidae Travassos, 1920, whereas others do not consider it closely related to this family.

Rothschild in 1936 recorded a forked tailed cercaria belonging to *Speloirema excellens* Nicoll, 1907 which normally possesses a single tail of the "ubiquita" group as a variation of the normal single tailed cercaria and denied the relationship of Gymnophallinae Odhner, 1905 with the Microphallidae. In 1937 she while referring to the "Stenostoma" type and "Mesostoma" type of excretory system in cercariae unequivocally denied the close affinity of the Gymnophallinae with Microphallinae so as to be included with it in the same family, though she thinks they are probably more closely related to each other than to Opisthorchioidea. She accepting the family Microphallidae Travassos, 1926 says that the knowledge of larval forms and life histories shows that the Micropallidae and Opisthorchioidea are not closely related. The Microphallidae possessing "Mesostoma" type of excretory system with the flame cell pattern 2 [(2+2)+(2+2)] = 16, and xiphidiocercariae which encyst in the first intermediate host or in an Arthropod resemble the Lecithodendriidae Odhner, 1910 of the Plagiorchioidea Dollfus, 1930. The cercariae, metacercariae and life cycle of *Maritrema* resemble those of the latter family.

Baer (1943) divided the Microphallidae into two families, Maritrematidae to include the genera possessing a cirrus sac and Microphallidae for those which lack it, though he admitted that the two groups are closely related. Cable and Kuns (1951) did not accept this subdivision into two families and traced the phylogeny of Microphallidae from "Archaic Plagiorchioid" closely related to the Lecithodendriidae. They think that *Microphalloids* Yoshida, 1938 represents the most primitive genus of the family as it possessess a cirrus sac, protrusible cirrus and vitellaria similar to those of the Lecithodendriidae, though its genital pore has shifted to the left side of acetabulum as typically met with in the Microphallidae. Their view that "The microphallids illustrate perhaps better than any other group what seems to be an axiom in the evolution of the digenetic trematodes : that reduction and loss of a protrusible cirrus and the cirrus sac essential to its function are accompanied by the development of accessory structures facilitating copulation and cross fertilisation" is quite sound. Baer (1943) and Cable and Kuns (1951) did not say anything about the Gymnophallinae while dealing with the Microphallidae. Cable (1952, 1953) created the genus *Parvatrema* with *Parvatrema borinquenae* as the genotype, of which he traced experimentally the life cycle. He showed that the minute cercaria of this genus is a cercaria of the Dichotoma group of furcocercous cercariae, which are larvae of the Gymnophallinae with short tail stem and furcae without setae of about equal length with two well

developed suckers, acetabulum situated behind the middle of body, long oesophagus, short intestinal caeca reaching a little beyond anterior margin of acetabulum, excretory vesicle filled with globules U-shaped or lyre-shaped, prominent caudal excretory canal with pores at tips of furcae, without flame cells in the tail, and with stenostomate protonephridia. The cercariae develop in simple short sporocysts with terminal birth pore in marine lamellibranchs. *Cercaria dichotoma* Muller of the genus *Gymnophallus* was obtained by Lebour, (1908) in the bivalve *Scrobicularia tenuis* and by Johnston (1904) in *Cardium edulae*. The unencysted metacercaria of *Parvatrema* was obtained by Cable by exposing marine snails *Carithidea costata* to infection with the cercaria. The minute metacercaria is an unencysted gymnophalline with many adult features developed including uterus but without eggs. It has prominent Y-shaped excretory vesicle with a very short stem and long arms reaching oral sucker filled with concretions, with stenostomate protonephridia and the flame cell formula the same as for the adult, *i.e.*, $2\,[(2+2)+(2)]$ 12 flame cells. Cable mentions that Rees (1939) has reported a formula $2\,[(2+2)+(2+2)]$ for the metacercaria of a *Gymnophallus* species. Most gymnophalline cercariae and metacercariae occur in lamellibranchs but the metacercariae of *P. borinquenae* and *Cercaria glandosa* Lebour, 1908 found in gastropods are exceptions. James recently (1960) described a unique type of 'parthenita' having all the essential features of a Gymnophalline cercaria, which develops in a gastropod mollusc *Littorina sexatilis*. The fully formed 'parthenita' is spherical with body surface covered with backwardly directed spines, subequal suckers, the gut consisting of pharynx, long oesophagus and two dilated caeca, Y-shaped excretory vesicle with the arms extending to posterior margin of pharynx and flame cell formula $2\,[(2+2)+(2)]=12$. It contains 20–2,000 tailless cercariae and closely resembles a tailless Gymnophalline cercaria, which in its development passes through a furcocercous stage, but the tails are spineless and immobile. During further development of the furcocercous stage, the tail degenerates and a cavity containing germ balls is formed resulting in the tailless 'parthenita'. In the developing furcocercous cercaria the excretory bladder is Y-shaped with flame cell formula $2[(1)+(1)]=4$. The germ cells of the fully formed tailless cercaria equivalent to unencysted metacercaria instead of giving rise to the gonads of the adult continue to multiply to produce furcocercariae by polyembryony with the result that the cercaria or rather the metacercaria is a 'parthenita'. The life cycle is thus a modification of the ordinarily Gymnophalline life cycle in that no sporocyst occurs in the life cycle. The Gymnophallinae thus characterised by the Dichotoma furcocercous character of their cercariae and the unencysted tailless metacercariae developing in marine lamellibrachs or gastropods with sporocyst or metacercaria as germinal sac show a peculiar specialization in their life cycle and therefore stand quite apart from Microphallidae Travassos.

Cercaria milfordensis from the marine bivalve *Mytilus edulis* described by Uzmann (1953) is a small microcercous distome with a small spherical tail and Y-shaped excretory bladder with stem shorter than the arms. Stunkard and Uzmann (1959) discovered that this cercaria is the larval stage of *Proctoeces* Odhner, 1911 which is a member of the family Fellodistomidae. Freeman and Llewellyn (1958) pointed out that as the excretory vesicle in this genus has an epithelial lining, it controverts La Rue's division of Digenea into Anepisthocystidia in which the family Fellodistomidae is included on account of its nonepithelial bladder.

Cercaria myae Uzmann, 1952 from the marine bivalve *Mya arenaria* possessing tail stem about one third of body length and slightly shorter than furcae provided with setae on posterior surface at the end, acetabulum about equal in size to the

oral sucker, well developed pharynx, short oesophagus and large caeca extending beyond middle of acetabulum, two pairs of penetration glands, U-shaped excretory vesicle with long arms and a caudal canal opening at ends of furcae and developing in motile sporocysts, and *C. discursata* Sinitzen, 1911, which develops in marine bivalve *Abra alba* of the Black sea and sheds its well developed forked tail in the simple sporocyst in which it develops, resemble one another closely. They possess the digestive and excretory systems similar to those of Fellodistomids. We think that *C. milfordensis*, *C. myae* and *C. discursata* belong to the adults of the family Fellodistomidae, Woodcock, 1912.

Cable (1953) included Gymnophallinae, Fellodistomidae and Brachylaemidae in the superfamily Brachylaemoidea Allison, 1942 on the basis of their morphological resemblance and similarity of the trichofurcous cercaria found by him developing in a marine bivalve at Puerto Rico, to the larva of *Bacciger bacciger* described by Palombi (1934) and to the *Cercaria trichofurcata* Johnston and Angel (1940) believed by the latter to be the larva of a species of *Tandanicola* (Monodhelmin thidae). He amended the family Fellodistomidae by including in it the subfamilie-Fellcdistominae Nicoll, 1909, Haplocladinae Odhner, 1911, Tandanicollinae Johnston, 1927 and Gymnophallinae Odhner, 1905. Cable thus considered the latter-sub-family to be more closely related to Fellodistomidae than to any other family of digenetic trematodes. We agree with this but disagree with his view that the differences between them are not so great as to justify the creation of a distinct family for the Gymnophallinae ; on the other hand, we accept the family Gymnophallidae Dollfus, 1939 which Dollfus created in his discussion and subdivision of the Troglotrematidae Braun, 1914. According to him Gymnophallidae stands parallel to the Renicolidae Dollfus, 1939.

Cable (1954) described a non-ocellate trichocercous cercaria—*Cercaria laevicardii* from a marine lamellibranch developing in simple sporocysts resembling the cercaria of *Bacciger bacciger* reported by Palombi (1934) and the one reported by him in 1953 as mentioned above. He traced the development of the excretory system in this cercaria. As the tail develops the excretory tubules extend into the tail and open separately at the tip before the lateral caudal finlets composed of setae are formed. Later the caudal tubules fuse and the resulting canal becomes large and prominent as in the furcocercous larva of the Fellodistomidae. The fused caudal canal bifurcates just before reaching the posterior tip of the tail at embryonic excretory pores. The excretory vesicle is U or almost V-shaped with large refractile concretions and wide arms extending anteriorly to ventral sucker with Stenostomate protonephridia and the flame cell formula $2[(3+3)+(3+3)]=24$ flame cells. He thinks that the larvae of the Fellodistomidae are basically furcocercous and discusses their various caudal modifications. The unnamed fork-tailed cercaria described by Jones and Rothschild (1932) with very short stem and very long slender furcae developing in simple sporocysts in *Nucula nucleus* is one of these modifications belonging to the family. We agree with him in this and also in that the trichocercous cercariae with simple unforked tail or forked tail are characteristic of the Fellodistomidae. But we do not agree with him in his interpretation that the caudal reduction of these cercariae indicates a resemblance showing close relationship with the Brachylaemidae and Bucephalidae and their inclusion with the latter families in the order Strigeatoidea. Cable's concept of the subdivision of the Digenea into two orders Strigeatoidea and Prosostomata has been modified by us in that the evolution of the Digenea has taken place along three divergent lines, one giving the order Fasciolatoidea Szidat, 1936, syn. Echinostomida La Rue, 1957 the second giving the orders Gorgoderida Mehra, 1958, Azygiatoidea Mehra, 1957 and the Hemiuratoidea Mehra, 1957 and the third

giving the order Strigeatoidea La Rue, 1926. It is possible that the superfamily Fellodistomoidea which we include in the suborder Fellodistomata Singh, 1960 under the order Fasciolatoidea Szidat stands near the point of divergence of the three evolutionary lines. The furcocercous cercariae which are met with in all the orders of the three phylogenetic lines and are characteristically modified due to specialization in the Hemiuratoidea are polyphyletic and not monophyletic as La Rue (1957) holds.

La Rue's 1926 concept of Digenea does not recognise the order Prosostomata. The Strigeatoidea La Rue, 1926 previously belonged to the latter order except its suborder Bucephalata which was known as Gasterostomata. So Cable's recognition of the two suborders Strigeatoidea and Prosostomata in Cable's 1954 paper is not upheld. It seems necessary to divide Digenea into more than two orders in the light of La Rue's modification of his concept (1957). But his two superorders Anepitheliocystidia and Epitheliocystidia are not tenable. Cable (1954) also admits this "In the Strigeatoidea, the excretory vesicle of the cercaria is always thin walled, whereas in the Prosostomata it may be either thin or thick walled, the latter condition being evidently a secondary one". He also mentions that as the Fellodistomidae have the genital pore anterior to the ventral sucker, they stand apart from the Strigeatoidea in which the genital pore is at the posterior end of body or closer to that end than to anterior extremity except in some blood flukes. Thus it becomes necessary to divide Digenea into the orders Gorgoderida Mehra, 1958 Azygiatoidea Mehra, 1957, Hemiuratoidea Mehra, 1957, Fasciolatoidea Szidat, 1936 syn. Echinostomida La Rue, 1957 and Strigeatoidea La Rue, 1926 as done by us (1957, 1960). The cystocercous character of the cercariae of first three orders being monophyletic establishes their closer affinity. There are some border line families standing near the divergence of some of these three lines of evolution. The family Oesophagicolidae Mehra, 1962 of Hemiuratoidea stands between the orders Fasciolatoidea (suborder Opisthorchiata) and Hemiuratoidea. The family Arnolidae Mehra, 1962 belonging to the Hemiuratoidea stands on the border line between this order and Azygiatoidea Mehra, 1957.

Yamaguti (1958) has created a new subfamily Baccigerinae for *Bacciger* Nicoll, 1914 under the family Cryptogonimidae Ciurea, 1933. It is not correct to assign *Bacciger* and the subfamily Baccigerinae Yamaguti to the family Cryptogonimidae. It is well known that the superfamily Opisthorchioidea Vogel, 1934 in which Price (1940) includes the latter family are characterised by possessing Pleurolophocerca and Parapleurolophocerca cercariae. Lundahl (1941) in his account of the life history of *Caecincola parvulus* has shown that the cercariae possess the character of Pleurolophocerca group, develop in rediae, penetrate and encyst in the fins and underneath the skin of various centrarchid and cyprinoid fishes which serve as second intermediate hosts. The development of the excretory system in these cercariae is similar to that of the opisthorchids. The short caudal excretory tube resulting from the union of the primary tubes in the tail in the cercarial embryos disappears after the formation of the epithelial vesicle. So the life cycle of the Cryptogonimidae is altogether different from that of *Bacciger bacciger* Palombi (1934) and *B. laevicardii* Cable (1951), which possess a trichocercous cercaria. The latter author has taken into account the life cycle of *Fellodistomum felis* as described by Chubrick (1952) while comparing his trichocercous cercaria, *Cercaria laevicardii* and cercaria of *Bacciger bacciger*. Yamaguti (1934) thus describes cercaria of *Bacciger harengulae* Yamaguti, 1938 "From analogy to Palombi's observation it is certain that the cercaria of this species is a setiferous one which was found by Fugita in 1906 and determined in the following year as *Cercaria*

pectinata Huet, 1891, and redescribed by Kobayashi in 1922 under the name Trichocercous cercaria A." The oval to pyriform cercaria with tail twice as long as the body and with V-shaped excretory vesicle having zig zag arms is produced in slender sporocyst with birth pore at one end. The conspicuous caudal canal bifurcates into short divergent tubules opening out to exterior on the tip of the tail. The tail is provided with short hairs and on each side with 24–25 rays consisting of 6–8 setae, the central one being the longest. The setiferous tails are shed off from the cercariae and degenerate in the sporocyst. The encysted metacercariae are set free in the branchial chamber of the snail and pass outside the shell.

It may be mentioned that Manter (1947) considered *Bacciger harengulae* Yamaguti, 1938 as one of the Fellodistomidae. He says "The genus *Bacciger* usually has been classified in the family Fellodistomatidae, but Yamaguti (1938) considered it in the family Heterophyidae. All Fellodistomids possess a cirrus sac which seems to be the chief character separating the two families". In view of the findings cercaria of *Bacciger harengul e* Yamaguti, the life cycle of Cryptogonimidae and *Bacciger* cited above and Manter's remarks about the morphology of *Bacciger* we have no doubt that the subfamily Baccigerinae Yamaguti, 1958 with *Bacciger* Nicoll, 1914 as its genus belongs to the family Fellodistomidae.

Cable (1953) as mentioned already has assigned subfamily Tandanicolinae Johnston, 1927 to the family Fellodistomidae. Yamaguti (1958) rightly includes it in the family Monodhelminthidae Dollfus, 1937. Dollfus (1937) created the genus *Monodhelmis* with *Monodhelmis torpedinis* as the genotype of his new family Monodhelminthidae. Srivastava (1939) while assigning his new genus *Mehratrema* to the latter family created two subfamiles Monodhelminae which name Yamaguti (1958) amends as Monodhelminthinae and Mehratreminae placing *Mehratrema* in the latter subfamily. Gupta (1956) created the genus *Buckleytrema* which belongs to Mehratrematinae. Yamaguti (1958) has dropped the subfamily Mehratreminae Srivastava and includes both the genera *Monodhelmis* Dollfus, 1937 and *Mehratrema* Srivastava under the subfamlly Monodhelminthinae Srivastava, 1939. The family Monodhelminthidae closely resembles the family Fellodistomidae on account of U or V-shaped excretory bladder with long arms reaching to level of oesophagus, stenostomate type of protonephridial system, acetabulum being well apart from oral sucker, genital pore preacetabular, cirrus sac present or absent, adults parasitic in fishes and cercaria of Tandanicolinae being trichocercous according to Johnston and Angel, 1940. The family differs from the Fellodistomidae characteristically on account of its genital atrium being provided with a posterior muscular accessory organ or genital pore sucker like with accessory organ for copulatory function and absence of cirrus. The family Monodhelminthidae Dollfus, therefore, belongs to the superfamily Fellodistomoidea of the suborder Fellodistomata, Singh, 1960.

It may be mentioned again as has been already shown by Cable and Kuns (1951) that the development of accessory copulatory apparatus in connection with the genital atrium has been independently evolved in distantly related families due to convergence. In Monodhelminthidae Dollfus which is closely related to the Fellodistomidae, it has been separately evolved from that of the families of the Opisthorchioidea Vogel. In the families Haploporidae and Waretrematidae of the superfamily Haploporoidea Mehra, 1962 loss of cirrus sac has been compensated by development of the hermaphroditic duct and hermaphroditic sac containing vesicula seminalis interna, prostate complex, ductus ejaculatorious and metraterm.

The Microphallidae Travassos assigned to the superfamily Plagiorchioidea Dollfus, 1930, possesses xiphidiocercariae of the Ubiquita type with undeveloped ventral sucker and digestive system, or of the Armatae type with ventral sucker, developing in sporocysts. The adults of the family parasitic in fishes, birds and mammals have a long oesophagus and short widely divergent caeca, small acetabulum, excretory bladder V or Y-shaped situated at the posterior end of body, mesostomate protonephridia. Yamaguti (1958) is not correct in assigning the subfamily Gymnophallinae Odhner, 1905 to the Microphallidae Travassos, 1920. We as already mentioned recognise it as the family Gymnophallidae Dollfus, 1939 and consider it to be closely related to the Fellodistomidae, and include it with the latter family and Monodhelminthidae under the superfamily Fellodistomoidea.

Yamaguti (1958) has created for the genus *Parvatrema* Cable, 1953 a new subfamily Parvatreminae under the Microphallidae. The genus *Parvatrema* is so closely related to *Gymnophallus* Odhner that the subfamily Parvatreminae is unnecessary and should be dropped. The morphological differences between these two genera, which are parasitic in birds and have furcocercous cercariae of the dichotoma group and unencysted metacercariae should be considered to be only of generic value.

Suborder Fellodistomata Singh, 1960.

Diagnosis : Fasciolatoidea. Suckers well developed and well apart. Genital pore preacetabular. Cirrus sac present or absent. Cercariae furcocercous with short tail stem, a little longer or much longer furcae and caudal canal running through tail without flame cells or cercariae simple nonbifid tailed setiferous (trichocercous) or trichofurcocercous (furcosetiferous) with lateral finlets composed of setae with caudal canal extending throughout tail stem and furcae without flame cells ; rarely microcercous. Excretory vesicle U–, lyre–, V-shaped with long broad arms or Y-shaped with short stem and long arms. Protonephridia stenostomate. Cercariae develop in sporocysts in marine lamellibranchs, rarely gastropods. Metacercaria unencysted in molluscs. Two or three host life cycle.

Superfamily : Fellodistomoidea for Fellodistomatoidea La Rue, 1957.

Diagnosis : The same as for the suborder Fellodistomata Singh, 1960.

Fellodistomidae Woodcock, 1912.
syn. Fellodistomatidae (Nicoll, 1913),
Steringophoridae Odhner, 1911.

Diagnosis : Fellodistomoidea. Body rather stout, ususally elongated, oval or pyriform. Oral sucker and acetabulum well developed and well apart. Acetabulum large, usually larger than oral sucker, sometimes subequal. Prepharynx usually absent ; pharynx present ; oesophagus short or moderately long ; caeca short or of moderate length, sometimes long. Genital pore median, submedian or lateral, preacetabular. Testes symmetrical, oblique or tandem. Cirrus sac small usually not extending behind acetabulum. Ovary usually pretesticular, sometimes intertesticular or post-testicular. Vitellaria preacetabular or postacetabular, rarely both preacetabular and postacetabular but never reaching posterior end. Uterus usually large, coiled with many ova, postacetabular. Excretory vesicle V or U-shaped with long broad arms or Y-shaped with short stem and long arms reaching pharynx and not united anteriorly ; protonephridia stenostomate. Cercariae develop in simple sporocysts in marine lamellibranchs, rarely gastropods ; metacercariae unencysted in molluscs. Two or three host life cycle. Parasitic in marine or brackish water fishes.

Type genus : ***Fellodistomum*** **Stafford, 1904.**

Key to the subfamilies of Fellodistomidae

Body long slender ; caeca single opening into excretory vesicle.....Monascinae Yamaguti, 1958.

Body not slender, caeca double.....1.

1. Cephalic projections and cervical folds present.....Tergestiinae Yamaguti, 1958.

   Cephalic projections and cervical folds absent.....2.

2. Excretory vesicle consisting of two long symmetrical tubes reaching pharynx ; oesophagus bifurcating behind acetabulum.....Symmetrovesiculinae Yamaguti, 1958.

   Excretory vesicle ordinary ; oesophagus bifurcating anterior to acetabulum.....3.

3. Caeca united posteriorly ; testes at posterior extremity.....Piriforminae Yamaguti, 1958.

   Caeca not united posteriorly ; uterus extending behind testes.....4.

4. Ovary post-testicular.....5.

   Ovary pretesticular.....6.

5. Cirrus sac thin walled overlapping acetabulum.....Baccigerinae Yamaguti, 1958.

   Cirrus sac well developed, muscular mostly anterior or dorsal to acetabulum.....Antorchiinae Yamaguti, 1958.

6. Vitellaria largely or entirely pretesticular or preacetabulur.....Fellodistominae Nicoll, 1909.

   Vitellaria largely or entirely post testicular or postacetabular.....7.

7. Body with ventrolateral muscular folds or lobes on each side or boat-shaped incurved ventrally ; excretory vesicle V-shaped.....Lissolomatinae Yamaguti, 1958.

   Body without above character ; excretory vesicle Y-shaped.....Heterorchiinae Dollfus, 1950.

Subfamilies Heterorchiinae Dollfus, 1950, Symmetrovesiculinae Yamaguti, 1958, Tergestiinae Yamaguti, 1958, Lissolomatinae Yamaguti, 1958 and Piriforminae Yamaguti, 1958 are tenable and for their diagnosis Yamaguti (1958) should be consulted. Subfamily Baccigerinae Yamaguti, 1958 is included in this family. Subfamily Pentagramminae Yamaguti, 1958 is dropped. It is considered synonymous to Antorchiinae Yamaguti.

Fellodistominae Nicoll, 1909

syn. Discogasteroidinae Srivastava, 1939

Diagnosis : Fellodistomidae. Body small, muscular usually plump, elongate or oval, spinulate or unspinulate. Suckers well developed. Acetabulum larger, usually equatorial or post-equatorial, sometimes modified into a specialized muscular discoid adhesive organ. Caeca short saccular to long, terminating anterior to acetabulum or at acetabular level. Genital pore preacetabular, behind pharynx, submedian, lateral or submarginal. Testes usually symmetrical, postacetabular ;

cirrus sac preacetabular ; cirrus usually present ; vesicula seminalis winding or bipartite. Ovary pretesticular or partly intertesticular. Vitellaria largely or entirely preacetabular or acetabular. Uterus occupying mostly hind body and acetabular zone. Excretory vesicle V or Y-shaped. Parasitic in marine or brackish water fishes.

Type genus : *Fellodistomum* Stafford, 1904.

The two Indian genera are *Pseudodiscogasteroides* Gupta 1953 syn. *Discogasteroides* Strand, 1935 and *Yamagutia* Srivastava, 1939.

The subfamily Discogasteroidinae Srivastava, 1939 syn. Discogasterinae Srivastava, 1939 created on the character of peculiarly modified musculature of acetabulum is dropped. The genera *Discogasteroides* Strand, 1934 syn. *Discogaster* Yamaguti, 1934, *Paradiscogaster* Yamaguti, 1934, *Megalomyzon* Manter, 1947, *Pseudogasteroides* Gupta, 1953 and *Yamagutia* Srivastava, 1934 are included in the subfamily Fellodistominae Nicoll, 1909. The genus *Pseudodiscogasteroides* Gupta, 1953 created to include the two species *Discogasteroides indicus* Srivastava, 1939 and *D caranxi* Srivastava, 1939 is tenable as these species have a typical cup shaped acetabulum with the usual type of musculature and cavity, though it is large in size. These genera along with *Yamagutia* Srivastava, 1939 form a connected series within the subfamily Fellodistominae. The totality of organisation is taken into consideration and not only one organ acetabulum in the case of this subfamily.

Key to the Indian genera of the subfamily Fellodistominae Nicoll

Genital pore lateral near right body margin, acetabulum not very large... ... . *Yamagutia* Srivastava, 1939

Genital pore median, acetabulum very large .... *Pseudodiscogasteroides* Gupta, 1953.

Pseudodiscogasteroides Gupta, 1953

Generic diagnosis : Fellodistomidae, Fellodistominae. Body plump, small, spinulate. Oral sucker smaller than acetabulum. Acetabulum very large, cup shaped with a large cavity, equatorial and post-equatorial with usual musculature. Prepharynx small. Pharynx moderate sized. Oesophagus absent. Caeca short, club haped, horizontal just in front of acetabulum. Genital pore median, preacetabusar, just behind pharynx or bifurcal. Testes almost equatorial, post acetabular at about half distance between acetabulum and hinder end. Cirrus sac elongated, tubular, obliquely directed, extending to middle or hinder end of acetabulum ; vesicula seminalis bipartite. Cirrus small. Ovary intertesticular or pretesticular in front of right testis. Receptaculum seminis and Laurer's canal present. Uterus coiled behind acetabulum and in acetabular level. Vitellaria follicular, anterior between caeca and middle of oral sucker. Excretory vesicle Y-shaped. Parasitic in intestine of marine fishes.

Genotype : *Pseudodiscogasteroides indicus* (Srivastava, 1939) Gupta, 1953.

Other species : *Pseudodiscogasteroides caranxi* (Srivastava, 1939) Gupta, 1953.

Locality : Puri, Bay of Bengal (India).

Yamagutia Srivastava, 1939

Generic diagnosis : Fellodistomidae, Fellodistominae. Body plump, rounded anteriorly and pointed posteriorly. Unspinulate. Acetabulum large, much larger than oral sucker, typical with cavity, immediately post-equatorial. Prepharynx and pharynx small. Oesophagus long with a posterior oesophagial bulb-shaped

part. Caeca small, saccular, horizontal. Genital pore lateral near right body margin just behind right caecum, immediately preacetabular. Testes post acetabular, lateral, slightly asymmetrical near hind end. Cirrus sac horizontal, club-shaped. Vesicula seminalis bipartite. Cirrus present. Receptaculum seminis and Laurer's canal present. Uterus large coiled mostly postacetabular and in acetabular zone. Vitellaria lateral, of long irregular follicles extending from level of intestinal bifurcation to middle of acetabulum. Exeretory vesicle Y-shaped with short median stem. Parasitic in intestine of marine fishes.

Genotypes : *Yamagutia lateroporus* Srivastava, 1939.

Locality : Karachi, Arabian sea (Pakistan).

Subfamily Antorchiinae Yamaguti, 1958

Diagnosis : Fellodistomidae. Body plump, or flattened, elongate, oval or pyriform. Acetabulum pre-equatorial, subequatorial or equatorial. Caeca short terminating at about middle of body. Genital pore sub-median or median, just preacetabular, near intestinal bifurcation or prebifurcal. Testes symmetrical, anterolateral to acetabulum, in acetabular or postacetabular zone, just medcal or posterior to caecal ends. Ovary post testicular, submedian or median. Vitellarian follicles lateral, massed together outside caeca, sometimes overlapping them, mostly pre-equatorial commencing from intestinal bifurcation or pharynx to acetabular zone or a little further behind to a little in front of caecal ends. Uterus large, mostly post-testicular. Excretory vesicle V or Y-shaped. Parasisic in fresh water, brackish water or marine fishes.

Type genus : *Antorchis* Linton, 1911.

Indian genus : *Faustula* Poche, 1925, syn. *Orientophorus* Srivastava, 1935.

Key to genera of Antorchiinae according to Yamaguti.

Caeca shorter than oesophagus ; testes preacetabular, postcaecal..... .... *Antorchis.*

Caeca longer than oesophagus ; testes mainly postacetabular, intercaecal..... .... *Faustula.*

Genus *Faustula* Poche, 1925.
syn. *Orientophorus* Srivastava, 1935.

Diagnosis : Fellodistomidae, Antorchiinae : Body small, thick or plump, oval or pyriform, spinulate. Suckers quite apart from one another, nearly equal in size. Pharynx large ; oesophagus moderately long, short or absent. Caeca terminating at about midbody or a little more posteriorly. Testes lateral, symmetrically opposite in acetabular or postacetabular zone just medial to caeca. Cirrus sac large, anterior or dorsal to acetabulum or extendinig behind it, containing sigmoid or slightly coiled vesicula seminalis, well developed prostatic complex and short cirrus. Genital pore submedian or median, preacetabular, near intestinal bifurcation or behind pharynx. Ovary strongly lobed, post-testicular. Laurer's canal present. Receptaculum seminis absent. Receptaculum seminis uterinum present. Uterus much coiled, mostly post-testicular. Metraterm feebly muscular. Vitellaria follicular outside caeca sometimes overlapping them. Parasitic in fresh water or brackish water fishes.

Genotype : *F. keksooni* (MacCallum, 1918) Poche, 1925.

Indian species : 1. *F. brevichrus* (Srivastava, 1935) Manter, 1953.
syn. *F. chauhani* Gupta and Srivastava, 1960.
2. *F. gangeticus* (Srivastava, 1935),
3. *F. ilishii* (Srivastava, 1935) and
4. *F. clupii* (Srivastava, 1935).

Monascinae Yamaguti, 1958.
syn. Haplocladinae Odhner, 1911.

Diagnosis : Fellodistomidae. Body long, slender. Caeca single running on right side opening into excretory vesicle at hinder end. Acetabulum rather small near anterior extremity. Genital pore median, preacetabular. Testes tandem, in posterior half of body. Cirrus sac preacetabular. Vesicula seminalis bipartite ; ductus ejaculatorius small ; pars prostatica well developed. Ovary pretesticular in anterior half of body. Uterus filling up entire hind body. Vitellaria extending along each side between acetabulum and anterior or posterior testis, Excretory vesicle Y-shaped. Parasitic in intestine of marine fishes.

Type genus : *Monascus* Looss, 1907 syn. *Haplocladus* Odhner, 1911.

Indian species : *Monascus orientalis* (Srivastava, 1941) syn. *Haplocladus orientalis* Srivastava, 1941 in *Synaptura orientalis*, Bay of Bengal.

Baccigerinae Yamaguti, 1958.

Diagnosis : Fellodistomidae. Body oval, small. Cuticle spinulate. Suckers well developed, quite apart from one another. Acetabulum equatorial, subequal to oral sucker. Caeca short, reaching middle of body to testes level or slightly behind. Genital pore median, immediately preacetabular. Testes symmetrical immediately postacetabular partly in level with acetabulum, intercaecal. Cirrus sac small, thin walled, overlapping acetabulum. Vesicula seminalis bipartite. Cirrus absent. Ovary median, postacetabular. Uterus coiled, postacetabular, post-equatorial. Vitellaria follicular in a small compact group, extracaecal in each extracaecal field at bifurco-acetabular level. Excretory vesicle V-shaped. Parasitic in intestine of marine fishes.

Genotype : *Bacciger bacciger* (Rud., 1819) Nicoll, 1914.

The subfamilies Baccigerinae and Antorchiinae Yamaguti, 1958 are closely related.

Gymnophallidae Dollfus, 1939.

Diagnosis : Fellodistomoidea. Body small, oval or pyriform, spinulate. Acetabulum well developed but small and quite apart from oral sucker, subequatorial or just postequatorial. Oral sucker larger than acetabulum. Prepharynx absent ; pharynx small ; oesophagus and caeca short. Genital pore median, sometimes wide pit like, some distance in front of acetabulum or possibly within its cavity. Genital atrium simple. Testes symmetrical or slightly oblique, postacetabular. Cirrus sac absent. Vesicula seminalis anterolateral to acetabulum. Ovary lateral, pretesticular or in level with posterior testis. Vitellaria a compact mass of few follicles, paired or unpaired near median line close to acetabulum. Uterus filling post-testicular region and extending anterior to testes. Eggs very small, numerous. Excretory vesicle V- with long arms or Y-shaped with long stem and arms ; protonephridia stenostomate. Cercariae furcocercous of Dichotoma group or tailless developing in marine lamellibranchs, rarely gastropods. Metacercariae free, unencysted in molluscs. Cercariae of *Gymnophallus* usually seen with

tail shed off metacercariae, (furcocercous stage developmental only) forming a cavity giving tailless parthenita. Cercariae are thus produced in a germ sac that has all morphological features of cercaria (James, 1960). Three host life cycle.

Type genus : *Gymnophallus* Odhner, 1900.

Other genus : *Parvatrema* Cable, 1953.

Monodhelminthidae Dollfus, 1937.

Diagnosis : Fellodistomoidea. Body small, oval, pyriform or ellipsoid, spinulate. Acetabulum well developed, but usually small, smaller than oral sucker and simple, exceptionally large, imbeded in parenchyma (*Prosogonarium* Yamaguti, 1952). Prepharynx usually present. Pharynx small : oesophagus short or of moderate length ; caeca reaching some distance in front of hinder end or terminating a little behind acetabulum much in front of hinder end. Genital pore submedian or median postbifurcal. Genital atrium or sinus median, submedian large and plaited (*Monodhelmis*) or of complicated structure with several long chitinous arches with genital sucker (*Mehratrema*), sometimes modified to form an atrial or accessory sac (copulatory sac) or with a copulatory papilla. Testes two intercaecal, symmetrical or not (testes extracaecal in *Atractotrema*). Cirrus sac present or absent. Vesicula seminalis free or enclosed in cirrus sac. Pars prostatica free or enclosed in cirrus sac. Ovary pretesticular or partly intertesticular. Vitellaria lateral, follicular, postequatorial or postacetabular or preequatorial composed of a few large follicles lateral to testes or ovary (*Prosogonarium*). Uterus in postacetabular median field or rarely extensive, in whole body. Uterus in *Atractotrema* perforating cirrus sac to open at genital pore. Eggs small, sometimes moderately large, numerous. Excretory vesicle U or V-shaped with long arms reaching to level of pharynx. Cercaria possibly trichocercous as mentioned for *Tandanicola* by Johnston and Angel. Parasitic in marine and fresh water fishes.

Type genus : *Monodhelmis* Dollfus, 1937.

Other genera are *Mehratrema* Srivastava, 1939, *Buckleytrema* Gupta, 1956, *Tandanicola* Johnston, 1927, *Prosogonarium* Yamaguti, 1952, *Atractotrema* Goto et Ozaki, 1929. All these genera belong to their respeciive subfamilies, Monodhelminthinae Srivastava, 1939, Mehratrematinae nom. amend. for Mehratreminae Srivastava, 1939, Tandanicolinae Johnston, 1927, Prosogonariinae n. subf. and Atractotrematinae n. subf.

The subfamily Mehratrematinae is maintained on account of presence of a cirrus sac and genital sucker and arms of excretory vesicle converging in region of testes.

Family Atractotrematidae Yamaguti, 1939 is reduced to the rank of subfamily and included in Monodhelminthidae. The subfamily stands intermediate between Fellodistomidae Woodcock, 1912 and Monodhelminthidae. The genus *Atractotrema* resembles Fellodistomidae in the acetabulum being larger than oral sucker and being well apart from it, preacetabular position of genital pore, cirrus sac being situated in front of acetabulum and in the Y-shaped condition of the excretory vesicle. It resembles Monodhelminthidae in uterus confined to median field of hind body, presence of prepharynx, short oesophagus and moderately long caeca, twisted vesicula seminalis externa and extent of vitellaria. The Y-shaped excretory vesicle of *Atractotrema* is a slight modification of U or V-shaped vesicle of Monodhelminthidae. The posterior accessory organ or sac of genital atrium is absent in *Atractotrema*, but the terminal part of cirrus sac perforated by uterus

may be considered to be homologous to it, possibly representing a primitive condition leading to the formation of accessory muscular sac of genital atrium. *Atractotrema* closely resembles *Monodhelmis* and *Mehratrema* in the position of uterus confined to median postacetabular field. The testes in *Atractotrema* are extracaecal just in front of acetabulum occupying the same position as the intercaecal testes of *Prosogonarium* in that region. It appears that the latter have just migrated outside the caeca in *Atractotrema* and their position with respect to the ovary is almost the same in these two genera.

Key to the subfamiles of Monodhelminthidae Dollfus, 1937.

1. Genital atrium without posterior accessory sac or copulatory organ, uterus perforating cirrus sac ; excretory vesicle Y-shaped with short median stem ; testes extracaecal..... .....
.. ..Atractotrematinae n. subf.

   Genital atrium with posterior accessory sac or copulatory organ, uterus not perforating cirrus sac ; excretory vesicle U or V-shaped ; testes intercaecal..... .....2.

2. Caeca short, hardly extending behind acetabulum or middle of body ..
....Tandanicolinae Johnston, 1927.

   Caeca longer terminating near or a little distance in front of posterior extremity..... ....3.

3. Acetabulum embeded in parenchyma and complicated in structure with a central mass of gland cells ; uterus extending in entire length and breadth of body.....Prosogonariinae n. subf.

   Acetabulum simple ; uterus intercaecal and postequatorial .....4.

4. Cirrus sac and genital sucker absent ; acetabulum pre-equatorial ; testes juxtaposed..... .....Monodhelminthinae Srivastava, 1939.

   Cirrus sac and genital sucker present ; acetabulum postequatorial ; testes symmetrically opposite.....Mehratrematinae Srivastava, 1939.

Monodhelminthinae Srivastava, 1939.

Subafmily diagnosis : Monodhelminthidae. Body small, elongated. Oral sucker large, terminal, slightly muscular. Acetabulum small, pre-equatorial, simple, well apart from the oral suker. Prepharynx small. Pharynx elongated cylindrical. Genital pore median preacetabular, behind intestinal bifurcation. Genital sinus voluminous, complicated and plaited supported by rodlets. Testes post-acetabular, just postequatorial, juxtaposed, intercaecal. Vesicula seminalis tubular. Cirrus sac absent. Pars prostatica opening dorsally into genital sinus. Ovary entire, pretesticular. Uterus postequatorial, post-testicular, intercaecal. Vitellaria lateral, postacetabular, short from level of testes to a little in front of caecal ends. Excretory vesicle U or V-shaped with arms reaching to level of oesophagus or pharynx. Eggs numerous. Parasitic in intestine of marine fishes.

Type genus : *Monodhelmis* Dollfus, 1937.

Genotype : *Monodhelmis torpedinis* Dollfus, 1937.

Mehratrematinae Srivastava, 1939.

Subfamily diagnosis : Monodhelminthidae. Body small, elongated. Oral sucker larger than acetabulum. Acetabulum small, preequatorial or postequatorial, well apart from oral sucker pretesticular, partially or completely post testicular

Prepharynx small. Pharynx bulbose ; oesophagus short : caeca terminating near hinder end. Genital sucker well developed. Genital opening submedian, postbifurcal. Testes just preacetabular, or partially or completely postacetabular almost symmetrical or oblique, intercaecal. Vesicula seminalis externa absent. Cirrus sac well developed, elongated containing elongated bulb-shaped vesicula seminalis and tubular pars prostatica. Genital atrium complicated in structure with several long chitinous arches and genital sucker. Ovary entire, pretesticular immediately behind cirrus sac. Uterus large, coiled, intercaecal, post-testicular. Vitellaria follicular, lateral, extending from level of anterior end of ovary or basal end of cirrus sac to almost last quarter of body length. Eggs numerous. Excretory bladder U-shaped with long cornua reaching oral sucker, converging in region of testes. Parasitic in intestine of marine fishes.

Type genus : *Mehratrema* Srivastava, 1939.

Genotype and only species : *Mehratrema dollfusi* Srivastava, 1939 syn. *Mehratrema polynemusinis* Chauhan, 1943.

Key to genera of Mehratrematinae

Testes almost symmetrical, preacetabular ; caeca terminating near posterior extremity ; acetabulum equal to or slightly larger than oral sucker..... ....*Mehratrema* Srivastava, 1939.

Testes oblique, partially or completely postacetabular; caeca terminating much in front of posterior extremity ; acetabulum much smaller than oral sucker.....*Buckleytrema* Gupta, 1956.

I. Genus *Mehratrema* Srivastava, 1939.

Monodhelminthidae, Mehratrematinae: Acetabulum almost equal to or slightly smaller than oral sucker. Genital pore surrounded by genital sucker, submedian, postbifurcal. Genital artium large with thick muscular walls with basal part bearing muscular papillae surrounded by gland cells. Oesophagus short; caeca reaching near posterior extremity. Testes almost symmetrical, post-acetabular at about middle of body. Cirrus sac elongated, tabular to left of genital atrium. Ovary pretesticular, preacetabular. Vitellaria follicular, lateral, extending from level of anterior margin of ovary to last quarter of body length. Uterus large, much coiled behind genital atrium and cirrus sac. Excretory vesicle U-shaped, with long cornua; reaching oral suker, converging in testicular region. Parasitic in intestine of marine fishes.

Genotype : *M. aollfusi* Srivastava, 1939. syn. *M. Polynemusinis* Chauhan, 1943.

Mehratrema polynemusinis Chauhan, 1943 is identical and synonymous with *Mehratrema dollfusi* Srivastava, 1939. The essential points in which the description of these species differ are the genital sinus and metraterm. Chauhan describes "A characteristic big pear-shaped sinus referred by Dollfus (1937) as 'genital sinus' with highly muscular walls and deeply staining secretions inside it is a peculiarity of the species. It measures 0·16–0·23 × 0·85–0·21 mm. and is probably confused as a peculiar metraterm." Dollfus (1937) describes genital sinus of *Monodhelmis torpedinis* as a very voluminous plaited or folded ; ductus ejaculatorious penetrates genital sinus, there being no cirrus and cirrus pouch. We think that *Monodhelmis* Dollfus and *Mehratrema* Srivastava somewhat resemble in possessing the complicated large genital sinus. Srivastava's account of the peculiar metraterm obviously refers to the genital sinus. *Mehratrema* possesses a well developed genital sucker of about one third of the size of the acetabulum. Chauhan also mentions that the male genitalia opens into a well developed genital sucker. What he

shows in his figure as sinus of genital sucker is cavity of the sucker leading into the genital sinus. The so called highly developed metraterm of *M. dollfusi* consisting of a cup-shaped basal part and a bell-shaped upper part with several longitudinal chitinous arches inside represents the genital sinus, surrounded by deeply staining gland cells. It differs in detail from that of *Monodhelmis torpedinis* besides possessing the genital sucker. The presence of cirrus sac and genital sucker in *Mehratrema* Srivastava distinguish it from *Monodhelmis* Dollfus, we, therefore, maintain the subfamlly Mehratrematinae. In possessing a cirrus sac it is primitive, but in possessing a genital sucker it is specialized. The genital sinus opens to the exterior through the genital sucker. The metraterm in *M. polynemusinis* is not correctly described by Chauhan. It cannot be so long as to run forward "by the right side of acetabulum in between the testes ; takes a turn to the left along side the sinus of the genital sucker." He has obviously described it as the terminal part of uterus. The metraterm does not exist in *Mehratrema*, nor in *Monodhelmis* on account of the absence of cirrus. Srivastava's description of the excretory vesicle of *Mehratrema* is meagre. Chauhan has more precisely described it. The arms of the excretory vesicle converge in the region of the testes. *M. polynemusinis* resembles very closely *M. dollfusi* in the shape of cirrus sac, in the position of acetabulum, testes, ovary and genital sucker. They resemble closely in almost equal sucker ratio, size of the body and size of various organs and of position of vitellaria. Chauhan's differential features of his species are rather far fetched *e.g.*, spherical instead of pear-shaped vitelline follicles, disposition of uterine coils, submedian genital pore etc. So there is no doubt that *M. polynemusinis* Chauhan is synonymous with *M. dollfusi* Srivastava.

II. Genus *Bucklytrema* Gupta, 1956.

Monodhelminthidae, Mehratrematinae : Body elongate, smooth without spines. Oral sucker large, much larger than acetabulum. Acetabulum small, a little in front of midbody. Prepharynx distinct; oesophogus moderately long; caeca terminate in posterior half of body far in front of posterior extremity. Testes oblique near one another, almost equatorial, posterior testis definitely equatorial; anterior partially or completely overlapped by acetabulum. Cirrus sac elongated, tubular, enclosing vesicula seminalis and prostatic complex. Ovary pretesticular, entire, preacetabular, preequatorial, median, immediately behind cirrus sac. Genital atrium (genital sinus) large, muscular, median with large basal part bearing prominent muscular papilla and surrounded by gland cells. Genital pore median, postbifurcal, surrounded by sucker. Vitellaria follicular, short, lateral, extracaecal and intercaecal, extending from level of ovary to testes. Excretory vesicle U-shaped with long cornua. Prasitic in marine catfish.

Genotype : *B. indica* Gupta, 1956. Parasitic in catfish in Gulf of Manaar, India.

Tandanicolinae Johnston, 1927

Subfamily diagnosis : Monodhelminthidae. Body small and fairly broad, pointed anteriorly and rounded behind. Suckers well apart. Acetabulum a little larger than oral sucker, just post-equatorial and simple. Prepharynx absent; oesophagus short ; caeca short hardly extending behind acetabulum. Genital pore median, a little behind intestinal bifurcation. Genital atrium with muscular accessory organ (copulatory sac of Johnston). Vitellaria lateral, short composed of a small number of follicles, above caeca, preacetabular. Uterus post-testicular restricted to median field. Excretory vesicle U-shaped. Parasitic in air bladder of fresh water fishes.

Type genus : *Tandanicola* Johnston, 1927.

Genotype : *Tandanicola bancrofti* Johnston, 1927.

Prosogonariinae n. subf.

Subfamily diagnosis : Monodhelminthidae. Body small, flattened, pyriform to ellipsoid, more or less pointed anteriorly, broadly rounded behind. Acetabulum much larger than oral sucker and well apart from it, imbeded in parenchyma, subequatorial, complicated having central mass of gland cells and anterior wall of lamellar muscles. Genital pore median near intestinal bifurcation. Genital atrium large with accessory muscular sac behind. Prepharynx short ; pharynx small ; oesophagus moderately long ; caeca terminating some distance in front of hinder end. Testes symmetrical, preacetabular, intercaecal. Cirrus sac to right side near instestinal bifurcation. Vesicula seminalis and prostatic complex enclosed in cirrus sac. Ovary median divided into three large lobes, pretesticular and intertesticular. Vitellaria lateral consisting of a few large follicles overlapping caeca outside testes. Uterus large, occupying entire length and breadth of body, intercaecal and extracaecal. Metraterm strongly developed. Eggs numerous. Excretory vesicle U-shaped, cornua reaching anterior extremity. Parasitic in intestine of fishes.

Type genus : *Prosogonarium* Yamaguti, 1952.

Genotype : *Prosogonarium arii* Yamaguti, 1952.

Atractotrematinae n. subf.

Subfamily diagnosis : Monodhelminthidae. Body small, fusiform, broad with somewhat pointed ends. Acetabulum well apart from oral sucker, larger, simple, pre-equatorial. Prepharynx absent ; pharynx large ; oesophagus short ; caeca terminating some distance in front of hinder end. Genital pore preacetabular, median at about intestinal bifurcation. Testes symmetrical, preacetabular ; pre-equatorial, extracaecal. Vesicula seminalis externa tubular and winding. Cirrus sac preacetabular containing seminal vesicle. Ovary submedian, intertesticular closely preacetabular. Laurer's canal opening ventrally in front of posterior end. Uterus coiled in postacetabular median field perforating cirrus sac to open into common genital pore. Metraterm absent. Vitellaria lateral extending along entire length of caeca. Excretory vesicle Y-shaped with short stem bifurcating at level of caecal ends, cornua long extending to testes near intestinal bifurcation. Eggs moderately large, numerous. Parasitic in intestine of marine fishes.

Type genus : *Atractotrema* Goto et Ozaki, 1929.

Genotype : *Atractotrema fusum* Goto et Ozaki, 1929.

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STUDIES ON *SCOLOPENDRA MORSITANS* LINN., PART—III REPRODUCTIVE ORGANS

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[Received on November 20, 1962]

Introduction :

The reproductive organs of various Chilopoda have been studied by a number of workers, *viz.*, Muller (1829), Fabre (1855), Schaufler (1889), Verhoef (1902 and 1925), Blackman (1905), Chalande (1905), Attems (1926 and 1930) and Demange (1945 and 1946).

The genital organs in the family Scolopendridae have also been described by Heymons (1901) in *Scolopendra cingulata* Bucherl (1939 ; 1942*a* ; 1942*b*) in *S. viridicornis* and by Jangi (1956 and 1957) in *S. morsitans*. There are, however, some discripancies in their accounts ; and at many places details have not been given by them. A re-examination of these organs seems necessary.

Material and Method :

The animals were collected and reared in the manner described earlier (Shukla, 1963).

The study of the genital organs was carried out by dissecting them *in situ* or by taking them out in *toto*. The external genitalia were studied in the manner described by Bucherl (1942*a* and 1942*b*). It was, however, observed that the protrusion of the genitalia was also possible by merely plunging the live animal in warm water. It was also noted that when a starved animal was given milk, it sucked it voraciously and in very large quantity, and the distended intestine exerted enough pressure to protrude the genitalia to the extent required for the study.

Observations:

The *Scolopendra* is a bisexual animal. Males can be differentiated from the females externally (Shukla, 1960 and 1963). The reproductive organs are surrounded by the fat bodies and placed dorsally to the gut in the middle line occupying the posterior two thirds of the body. The gonopore lies on the ventral surface of the genital segment immediately in front of the anus.

A. The male reproductive organs :

The male reproductive organs (Figs. 1 and 4) consist of testes, vasa efferentia, vas deferens and accessory glands. The testes (Fig. 3) are in ten pairs and sausage-shaped. The two testes of each pair, bound in a common transparent sheath, are placed together. They lie obliquely one behind the other in a serial order, on the dorsal side of the vas deferens. The anterior-most pair of the testes is situated in the 7th segment of the body. Jangi (1956) describes however that the anterior end of the first pair lies in the 5th segment. From each testis arise two vasa efferentia one from each end.

The vasa efferentia (Fig. 3) are slender ducts. One duct arises from each end of the testis, thus from each pair of testes are given off two pairs of vasa efferentia, one pair from the anterior and the other from posterior end. The paired vasa efferentia of each end are bound together in a thin transparent membranous sheath. They run for a short distance along the testes on their ventral side to open into the vas deferens. Heymons (1901) wrongly describes that the vasa efferentia of the two ends of a pair of testes open together in the vas deferens. Demange (1946) was the first to point out more or less the correct position of the openings of the vasa efferentia into the vas deferens. He showed that the vasa efferentia of the two ends of the testes open separately and the posterior vasa efferentia of the anterior pair of testes and the anterior vasa efferentia of the following pair open into the vas deferens at the same level. Jangi (1956) has however shown that these vasa efferentia do not open at the same level but the posterior vasa efferentia of a pair open slightly ahead of the anterior vasa efferentia of the succeeding pair. My observations are in agreement with those of Jangi's (1956). I have however to add that these vasa efferentia open on the dorsal wall of the vas deferens facing each other and further that the vasa efferentia of the posterior end of the last pair of testes get seperated from each other as they reach the vas deferens and one of them proceeds ahead on the other side of the vas deferens after crossing its dorsal wall, then turns back to open into it seperately (Fig. 3).

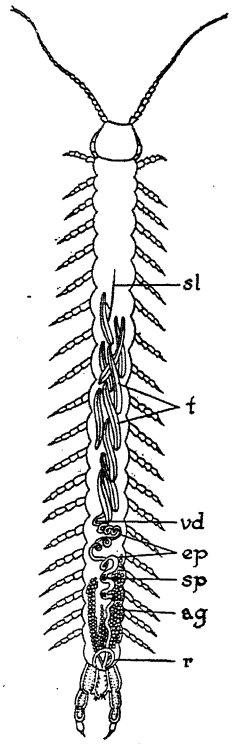

Fig. 1 Male reproductive organs.
ag, accessory glands ; ep, epididymis ; r, ring of vas deferens ; al, suspensory ligament; sp. spermatophore ; t, testes ; vd, vas deferen.

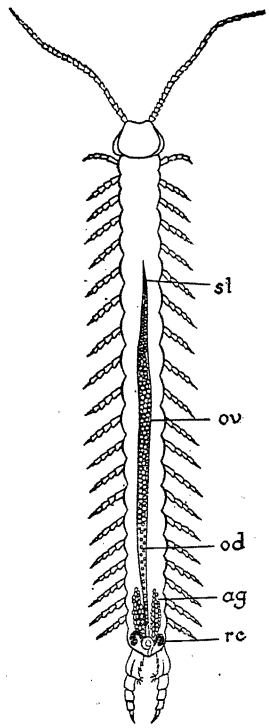

Fig. 2. Female reproductive organs.
ag, accessory glands ; od, oviduct ; ov, ovary ; rc, receptaculum seminis ; sl. suspensory ligament.

The vas deferens (Fig. 1) extends from the posterior region of the 6th segment as a fine cord. Jangi (1956), however, mentions this cord to be traceable as forward as the 4th segment. This may be true in his case when he mentions the pair of testes to be situated in the 5th segment (*vide supra*). It is held in position by the fat body surrounding it. This part of the vas deferens may be known as the suspensory ligament (Demange, 1946, names it "ligament suspenseur"). The vas deferens lies ventrally to the testes and as it runs posteriorly, the vasa efferentia open into it. It becomes thickened at places where the vasa efferentia open. Posterior to the region of the testes it becomes highly coiled and is known as the epididymis, the terminal portion of which becomes highly dilated and transparent. This region contains the spermatophores. In the 21st segment (Fig. 4) the vas deferens turns to the right of the rectum and then passes to the ventral side. Before taking its turn it gives out a long slender branch from its left side. This branch forms a ring round the rectum to meet the vas deferens proper. Their junction forms the atrium which ultimately communicates with the ejaculatory canal. The ejaculatory canal runs on the penis to open to the exterior through the gonopore situated at the tip of the penis.

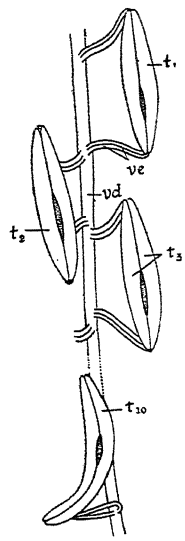

Fig. 3. A few testes enlarged. t_1, t_2, t_3, t_{10}, pairs of testes ; va, vasa efferentia ; vd, vas deferens.

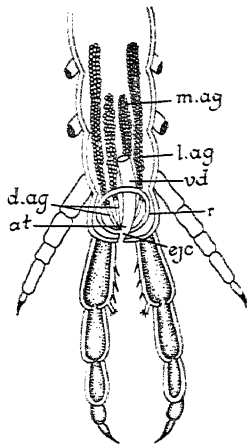

Fig. 4. Posterior part of the male reproductive organs enlarged.
at, atrium ; d.ag., duct of the assessory gland ; ejc, ejaculatory canal ; l. ag, lateral accessory gland ; m. ag, median accessory gland ; r, ring of vas deferens. vd, vas deferens.

Accessory glands : (Fig. 1 & 4). There are two pairs of accessory glands lying on the ventral side of the alimentary canal. The glands are dull-white in appearance and are made up of a number of lobes. The two pairs may be known as the lateral pair and median pair. (*i*) The lateral pair ("outer pair" of Jangi, 1956) is large extending anteriorly upto the 18th segment. The ducts of the two glands join together to open into the ejaculatory canal. (*ii*) The median pair ("smaller pair" of Jangi, 1956) is small lying in between the lateral pair.

They extend anteriorly upto the anterior part of the 19th segment and open seperately into the genital atrium. The names lateral and median pair given here are more appropriate than 'outer' and 'smaller' pair respectively.

The spermatophore : (Fig. 5). The spermatophores are found in the distended part of the epididymis arranged generally one behind the other. Demange (1945) has described the spermatophore in *Scolopendra subspinipes de haani* Brandt and *Cryptops anamalans* Newp. The spermatophore of *Scolopendra morsitans* is a bean or kidney-shaped whitish capsule which generally turns brown on exposing to the atmosphere. Their shape is not exactly similar even in the same specimen. The spermatophore has a longitudinal cleft on one side. The cleft extends through the major portion of it and is very distinct in the middle region but narrows down towards one end. Its wall consists of three layers which may be known as the external ("outer" of Jangi, 1956), the middle and the internal ("inner" of Jangi, 1956). The middle and external layers are very closely attached. This is why Jangi (1956) mentions to have been able to seperate only two coats although in sections three distinct layers have been noticed by him. Demange (1946) also states its wall to be made up of three envelops. The spermatophores contain bundles of spermatozoa.

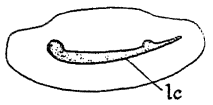

Fig. 5. A spermatophore.
lc, longitudinal cleft.

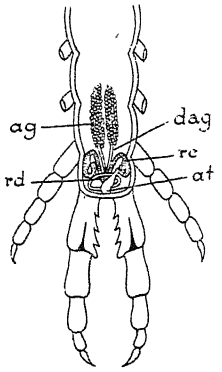

Fig. 6. Posterior part of the female reproductive organs enlarged.
ag, accessory gland ; at, atrium ; dag, duct of accessory gland ; rc, receptaculum seminis ; rd, duct of receptaculum.

B. The female reproductive organs :

The female reproductive organs (Fig. 2 & 6) consist of the ovary, the accessory glands and the receptacula seminales. The ovary is a single large median organ lying on the dorsal wall of the gut and extending anteriorly as far as the 7th segment of the body. Jangi (1957) mentions it to be extending upto the 8th segment only. It is surrounded by a thick layer of fat body. From the anterior end of the ovary runs a fine ligament extending upto the posterior end of the 5th trunk segment which may be known as the suspensory ligament ("Terminal filament" of Jangi, 1957). The anterior most part of the ovary is a narrow tubular structure which gradually becomes wider as it runs posteriorly. The ovary extends upto the 14th body segment posteriorly.

The ovary contains ova in the various stages of development. The ova are arranged in an irregular manner. The large and small ova remain intermingled. This arrangement is found throughout the ovary. In the young animals the ova are arranged singly but at places there may be two in a transverse row. In large animals there are two or even three ova in a transverse row.

The oviduct runs from the posterior end of the ovary, *viz.* from the end of the 14th segment. In fact the ovary passes into the oviduct imperceptively. It continues posteriorly and like the vas deferens, it also gives out a slender branch from its left side which goes down and makes a loop round the rectum. Heymons (1901) has named this loop "arcus genitalis". The main duct continues further along the right side. The two ducts do not join but open almost separately in the genital atrium in front of the opening of the receptaculum seminis.

The accessory glands (Fig. 6) are paired and situated on the ventral side of the gut laterally. The glands are white and made up of many lobes. They extend anteriorly upto the 19th segment where as Jangi (1957) mentions them to be extending forward to a point just beyond the 21st segment of the trunk. My observations are more or less in agreement with that of Heymons (1901) in *S. cingulata*, who mentions them to be extending still further than the 21st segment. The function of the gland is not known. The ducts of the two glands run posteriorly, approach near each other in the posterior part of the 21st segment and come to lie between the ducts of the receptacula seminis. The two ducts ultimately open into the atrium separately, their longitudinal slit-like apertures are placed close together. These openings are situated a little posteriorly to those of the receptacula seminales.

The receptacula seminalis (Fig. 6) are paired lying asymmetrically in the last segment of the body. They are however slightly extending even into the posterior part of the 20th segment. In younger animals they are whitish in colour but in full grown ones they become brown. They are large and ampulla-like, sometimes bent upon themselves. The receptacles are thin walled, their contents in preserved specimens become solidified. From the posterior end of each receptacle arises a duct, the two ducts run posteriorly on the outer side of the ducts of the accessory glands. The receptacular ducts ultimately open into the atrium slightly anterior and dorsal to the openings of the ducts of the accessory glands.

The genital atrium (Fig. 6) is a broad structure and opens to the exterior through the gonopore. A number of matured specimens were dissected but never an embryo was found in the atrium. However, Bucherl (1939) mentions the presence of two or four embryos in the atrium showing the formation of head and segmentation, in *Scolopendra viridicornis*. From his observations it is borne out that these animals are viviparous. He has further quoted Heymons (Entwicklungsgeschichte der Skolopender, *Bibl. Zool.* 1901) who observed the egg laying of European *Scolopendra*. Jangi (1957) has mentioned that the females lay a cluster of greenish yellow eggs which are elliptical in outline.

Summary :

There are ten pairs of testes, each pair bound together in a common sheath. From each testis arise two vasa efferentia, one from the anterior and the other from the posterior end to open into the vas deferens. The epididymis becomes dilated posteriorly and contains the spermatophores. The vas deferens forms a ring round the rectum and communicates with the genital atrium which is connected to the ejaculatory canal. The canal runs on the penis to open through the gonopore. The accessory glands are two pairs, the ducts of the lateral pair open into the

ejaculatory canal and those of the median pair into the genital atrium. The spermatophore is bean-shaped and has a longitudinal cleft on one side.

The ovary is single and contains ova of various developmental stages intermingled. The oviduct runs from the posterior end of the ovary and makes a loop round the rectum. The two branches of the loop do not meet but open separately into the genital atrium. The accessory glands are paired and their ducts open into the atrium. The receptacula seminalis are also paired and ampulla-like, their ducts also open in the atrium. The genital atrium open to the exterior through the gonopore.

Acknowledgments :

I wish to express my gratitude to Dr. Vidya Nand, Ph.D., St. Johns College, Agra, for his suggestions and valuable help in the preparation of this work.

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SEXUAL DIMORPHISM, FECUNDITY AND FOOD OF THE ESTUARINE BAGRID, *MYSTUS GULIO* (HAM.)*

By

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[Received on April 12, 1962]

Introduction :

While collecting material for a biological study of *Pangasius pangasius* (Hamilton) at Port Canning on the Matlah and the Kulti outfall region on the Kulti estuaries, a few miles from Calcutta, during 1954–55, the author found that, 75 to 180 mm. long (total length) *Mystus gulio* (Hamilton), a small Bagrid catfish, formed a considerable proportion of catches from these centres and connected brackish channels and 'Bheris'. The fish shoaled in large numbers and exceeded all other catches by volume and numbers during the spring tide days in June, July and August. Since almost nothing was known of its biology the author collected samples whenever he could and recorded the routine measurements of length, weights or sexes besides studying its food.

Distribution and Economics of its Fishery :

The fish is distributed along the sea coasts of India in estuarine back waters and other tidal waters from deltaic Bengal Southward, through the East Coast in the Mahanadi, Chilka lake, Godavary-Krishna rivers, Collair, Pulicat lakes and the Cauvery and minor other river tributaries, and through the West Coast in the back waters of Travancore-Cochin and short tidal ranges of Mysore through Bombay, Gujarat Coasts northwards upto the Indus delta. Its further westward distribution is obscure. It is equally well distributed in Burma, Ceylon, Thailand, Malaya Peninsula, Sumatra, Borneo, Java and Madeora (Smith, 1945). At least the species is not isolated to any particular geographic region, and its great adaptability from highly saline (it is recorded in the sea along the Travancore-Cochin *i.e.*, present Kerala coast) and even to marine conditions renders it versatile in distribution. By its prolific breeding, which must occur in fresh waters, considerable distribution and intermixing of the stock may even now be taking place along the coastal belts. The species is found in fresh water conditions far from its typical tidal haunts. David (1953) recorded the species from a solitary example at Dhama in the Mahanadi near the Hirakud region and 250 miles above the tidal limit. Hora and Misra (1942) have recognised the species in the headwaters of the Krishna 700 miles from the deltaic region in Poona district.

The maximum length attainable by the species is recorded as 250 mm. by Smith (*op. cit.*), even though he does not preclude possibilities of its attaining 500 mm. in East Indies. Day (1889) records an 18 inches (just over 450 mm.) long stuffed specimen in the Calcutta Museum. In Bengal throughout the observations, the author however, failed to recognise this fish beyond about 185 mm. Larger sizes being more vulnerable, have entirely been eliminated not having a fair chance to remain in natural waters beyond about two to three years of their life.

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Large numbers of this fish are netted by fixing traps and collapsible stake nets across the narrow fresh waters over channels connecting inundated areas and brackish tidal creeks in Lower Bengal during June, July and August months. Spring tide rises and rains favour such fishing. The species however, occurs all round the year in the fixed tidal bag nets—'Bheen' nets in the estuaries and the tidal Hooghly. Cast netting also serves to provide a number of individual fishermen with this fish from all the mud-flats of estuarine creeks. In the saltwater 'Bheris' *i.e.* saline fish ponds and other low lying brackish inundations, the fish generally forms a major item of fishery yield, along with various Mullets-*Liza* spp., Perch (Bhetki)—*Lates calcarifer* or various Penaeid Prawns. These fish are removed generally just before and during winter months from October to December. (Cultivated examples are not included in the present study). In the sewage affected Kulti estuary and connected 'Salt water' fisheries, *M. gulio* constituted one of the major fish yields even though all other fishes (except *Pangasius pangasius*) were eliminated (David, 1959). The species not only withstands wide fluctuations in salinity but also is much hardier than most other forms except *Pangasius pangasius*. Its high fecundity contributes not a little towards this extra-ordinary adaptability to varied conditions of water from extremes of fresh to saline, clear and unpolluted to polluted waters. It is, hence, not surprising that the form is of such wide and economic distribution almost across a quarter of the world's coastlines.

The species mainly caters to the poorer sections of the population in Bengal, as it is cheaper than many other forms. Its extreme numbers and fairly high fat contents, has made extraction of visceral oil in the Collair lake along the East Coast (between the Godavary and Krishna rivers) a profitable industry (Chacko, 1947). Economically it is not considered as of any great value along the West Coast of India as better fishes and prawns available there obscure its merits.

Material and Methods :

Samples of this fish were collected at Port Canning on the Matlah and Kulti on the Kulti estuaries, varying from 1 kgm to 3 kgm. Total length and weight were recorded from the minimum to the maximum ranges at random, recording sex, condition of gonad, food etc. from month to month.

The species showed a recognisable sexual dimorphism, the males possessing short genital papillae, which developed along with attainment of maturity of the testes, and disappeared as soon as the spawning season was over. There being no other outwardly recognisable character to distinguish the sexes, it was thought of some interest to ascertain if any other changes occur in the sexes in their length-weight relationships and morphometric characters. Separate measurements for the purpose were recorded and subjected to statistical analysis. Fecundity, growth increment, coefficient of condition and food studies were also made similarly.

Sexual Dimorphism :

Genital Papillae.—Minute muscular genital papillae in the males, were first noticed in May. By June—July when majority of males were ready for milting, except some that were still immature all showed these projections more prominently. Mookherjee, Muzmudar and Das Gupta (1941) have described the papillae with a diagram. Eggert (1930) also earlier referred to this papillae, but even earlier, Day (1889) had referred to such papillae in *M. keletius* (Cuvier and Valenciennes) and Hora and Law (1941*a*) to *M. malabaricus* (Jerdon) with figures. Further, such genital papillae do not seem confined only to the *Mystus* genus of the Bagridae family, but are noted also in Sisoridae family, such as *Gagata* and *Batasio* spp. (Hora and Law, 1941*b*). Mukherji (1936) recorded similar papillae in *Glyptosternum reticulatum* McClelland.

TABLE 1

Statistics for Regression of Weight on Total Length in Sexes of *Mystus gulio* (Hamilton)

Index	No.	Size Range (mms.)	sxy	sy^2	sx^2	Mean Log X	Mean Log Y	b	vb	r	Log C	Corresponding Length-Weight equation
Males Whole year	389	40–170	16·33465	50·07409	5·66776	1·93335	0·80077	2·99209	0·0013657	0·97024	−4·77131 or c = 0·00000169	Log. wt. = −4·77131 + 2·88209 Log. T. L.
April to August	178	56–153	6·15598	19·51987	2·04399	1·96317	0·87216	3·01176	0·0027231	0·97459	−5·04042 or c = 0·00000091	Log. wt. = −504042 + 3·01175 Log. T. L.
Females Whole year	565	37–186	31·90731	97·29742	10·98429	1·97360	0·97001	2·90481	0·0002036	0·97098	−4·76292 or c = 0·00000173	Log. wt. = −4·76292 + 2·90481 Log. T. L.
April to August	256	50–186	12·93486	41·82601	4·14455	1·99584	1·01789	3·12089	0·0033853	0·98241	−5·21091 or c = 0·00000062	Log. wt. = −5·21091 + 3·12089 Log. T. L.

Hora and Law's (1941*a*) observations that "the size of the papillae depends upon the sexual maturity of the individual irrespective of its length", is somewhat to be modified, as presence of a papilla indicates only onset of maturity in the male, hence all round the year the male cannot be distinguished readily from the female. Papillae have never been observed by the author between October and March in *M. gulio*. The protruberance starts as a small projection reaching a maximum length of upto 4 mm., in July—August in larger specimens of as much as 155·0 mm., when as small as 67·0 mm. (t.l.) show only a minute papilla. Once milting is over, it begins to shrink, ultimately disappearing by September. Hence it is only a secondary sexual character.

It is almost certain that in all other related catfishes such papillae if found, indicate the proximity or actual condition of spawning, rather than a permanent dimorphic character of the male.

Length-Weight Relationships.—Unless length-weight data so commonly obtained in connection with studies of fishes, interpret trends in their biology, mere expressions of regression equation remain largely useless. Moreover, various biases introduced during the course of investigations, are apt to be overlooked unless verified by known statistical tests. Hence lenghts and weights of *M. gulio*, were measured and noted separately each for males and females, and later pooled in two combinations. One pooled data was for the entire 12 months for each sex, and another pooled data was for five months between April and August, when fully ripe specimens were observed in each sex, at a period when the males exhibited genital papillae. Sexing was done in other months by cutting open the abdomen and examining the gonad, as described further.

Method adopted for length-weight relationship and other attendant coefficients, was by the two way frequency method as in a separate contribution referring to *Pangasius pangasius* (Hamilton) by the author (David, *Mss.*), where the procedure is described in detail.

TABLE 2

Analysis of covariance to test the differences between Length-Weight regressions of *M. gulio* in sexes during the whole year

	N	sy^2	sxy	sx^2	b
A—Females	565	97·29742	31·90731	10·98429	2·90481
B—Males	389	50·07409	16·33485	5·66770	2·88209
Total	954	147·37151	48·24216	16·65199	

$$S.S. = sy^2 - \frac{(sxy)^2}{sx^2} = 147{\cdot}37151 - \frac{(48{\cdot}24216)^2}{16{\cdot}65199} = 7{\cdot}6099$$

Test of Significance of b for A and B

	b sxy (Sum of squares due to regression)	$sy^2 - b\,sxy$ (Residual sum of squares)	D.F.
A	92·68464	4·61278	564
	47·07851	2·99588	388
	Total	7·60836	952

Source of Variation	D.F.	S.S.	M.S.
Deviation from total average regressions	953	7·6099	
Deviation from individual regressions within samples	952	7·6084	0·00799
Difference	1	0·0015	

$$F = \frac{0.0015}{0{\cdot}00799} = 0{\cdot}1878 \qquad \text{NOT SIGNIFICANT}$$

Table 1 gives all values including variance of 'b' *i.e.* "vb" and "r" which check the correctness of the final equation arrived at. It is observed that "vb" values in all four cases are low indicating that there is little heterogencity or bias in the ranges and numbers of fish examined. "r" automatically being less than 1 in all cases, verifies further that sampling error was little and the measured examples are truly representative of the population.

The regression slope or the coefficient "b" indicates that the males over the whole year are little different from the females over the whole year. "F" value is 0·1878 which is not significant (table 2). Both slopes are parallel to each other as shown in the regression lines drawn on a double logarithmic grid using the equivalent equations (fig. 1).

TABLE 3

Analysis of Covariance to test the Differences between Length-Weight Regressions of *M. gulio* in sexes during breeding seasons

	N	sy^2	sxy	sx^2	b
A—Females	256	41·82601	12·93469	4·14455	3·12089
B—Males	178	19·51987	6·15598	2·04399	3·01175
Total	434	61·34588	19·09066	6·18854	

$$S.S. = 61{\cdot}34588 - \frac{(19{\cdot}09066)^2}{6{\cdot}18854} = 2{\cdot}45424 \text{ for } 433 \text{ D.F.}$$

Test of Significance of b for A and B

	b. sxy	sy^2 - b. sxy	D.F.
A—Females	40·36771	1·45830	255
B—Males	18·54027	0·97970	177
Total		2·43800	432

Source of Variation	D.F.	S.S.	M.S.
Deviation from Total Average Regression	433	2·45424	
Deviation from Individuals within Samples	432	2·43800	0·005643
Differences	1	0·01624	

$$F = \frac{0{\cdot}01624}{0{\cdot}005643} = 12{\cdot}8779$$ HIGHLY SIGNIFICANT

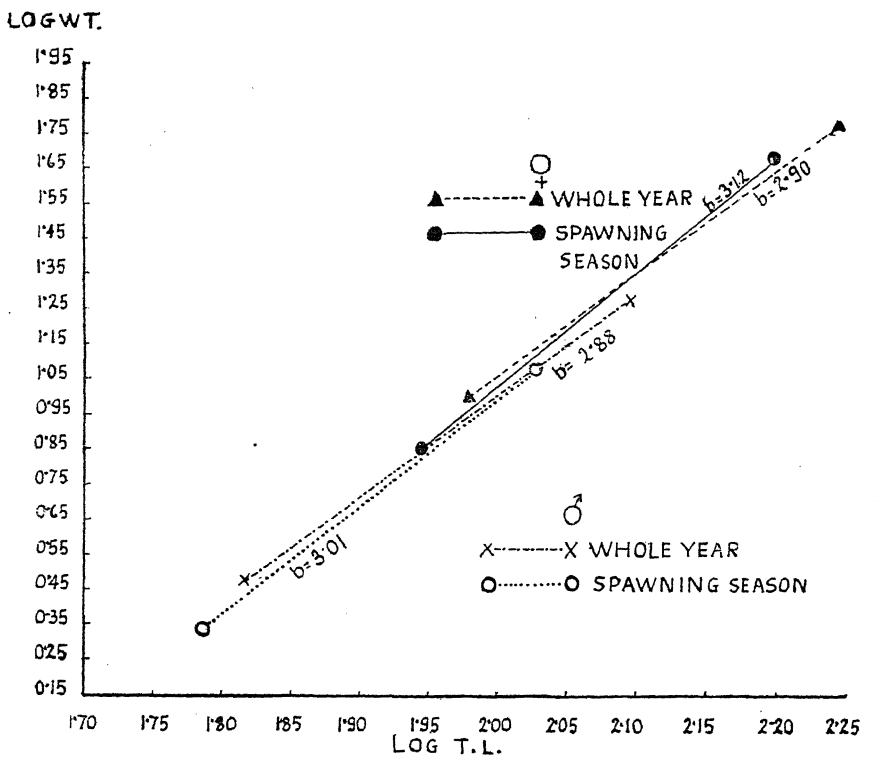

Fig. 1. Regression lines for Length—Weight coefficients drawn separately for the males and females during the whole year and for the spawning months (April—August). The lines indicate the insignificant differences between sexes over the whole year as against significant differences during spawning months.

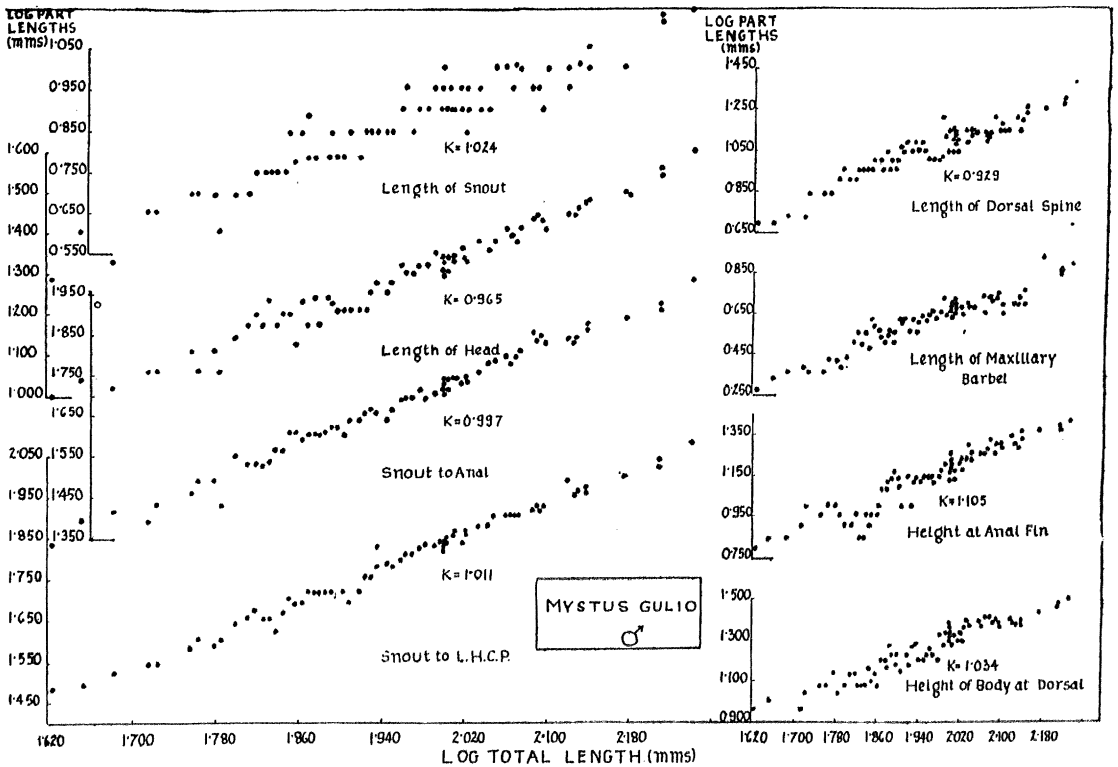

Fig. 2. Scatter diagrams of body parts against total lengths (in log values) in males plotted on a double logarithmic grid. Lengths of Maxillary Barbels and Dorsal Spines show slight signs of bradyauxesis after 91·0 mm. (T. L.). Coefficient K for Dorsal Spines has been disregarded as it shows a curvilinear nature.

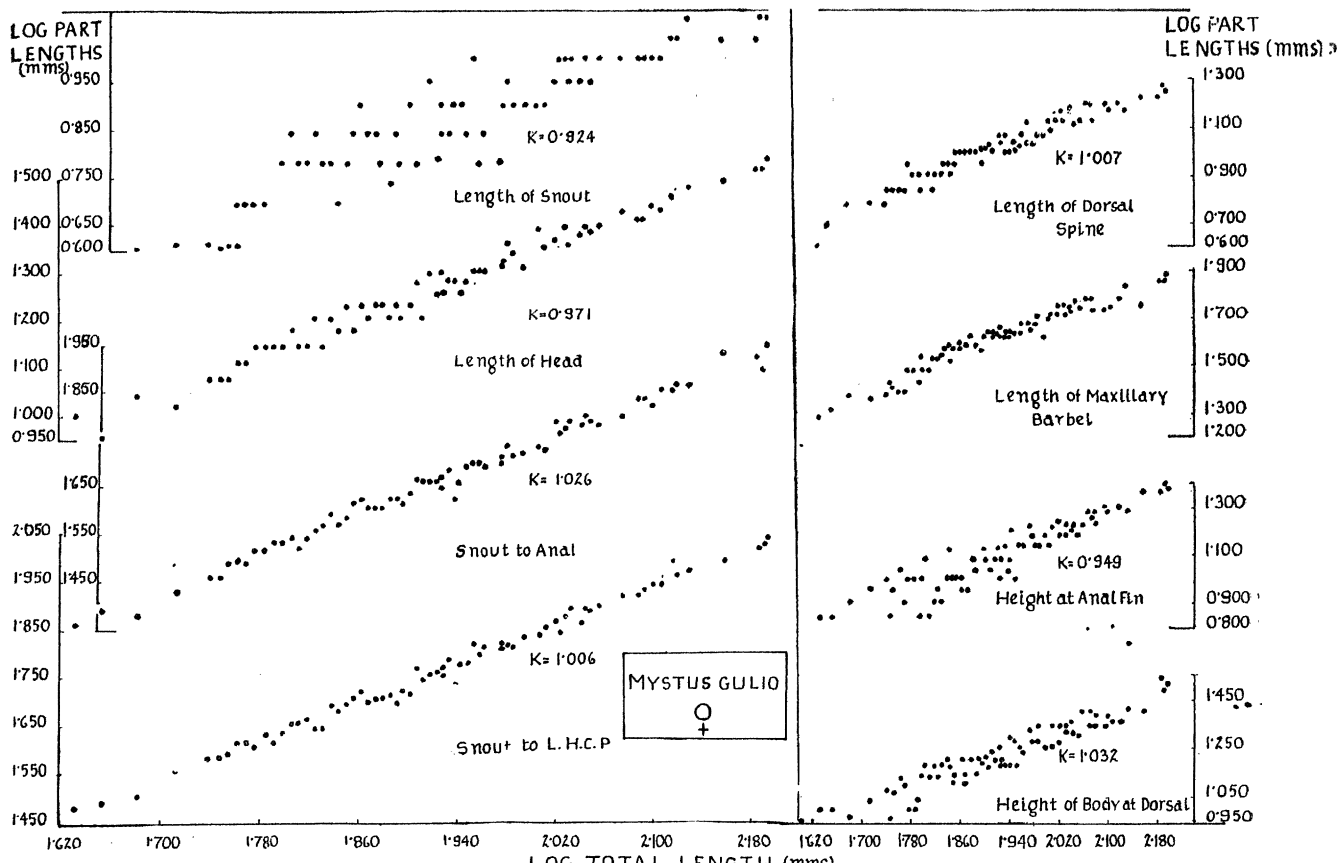

Fig. 3. Scatter diagrams for the females of *M. gulio* also show similar trends already noted in males. However the coefficient K differ and bring out differences in the appropriate 'F' tests.

TABLE 4

Sexual Dimorphism in *Mystus gulio* (Hamilton) : Sums of Variates, Square and Products (Total Length —X and Variate Y)

Variate	N	SX	SY	SXY	SX^2	SY^2	X	Y	sx^2	sy^2	sxy	Regression Coefficient (b)	D.F.	b. sxy	sy^2–bsxy	D.F.
Snout to L. H. C. P.																
Females.	50	98·12574	90·05411	177·61390	193·44918	163·09025	1·96251	1·80108	0·87644	0·89560	0·88181	1·00613	49	0·88721	0·00839	48
Males.	50	98·05406	89·92361	177·03313	192·97034	162·43294	1·96108	1·79847	0·67849	0·70801	0·63575	1·00168	49	0·69306	0·01495	48
Sexes Combined.	100	196·17980	179·97772	354·64703	386·41952	325·52317	1·96179	1·79977	1·55595	1·60467	1·56854	1·00809	99	1·58123	0·02344	98
Snout to Anal Fin																
Females	50	98·12574	84·69753	167·11910	193·44918	144·40773	1·96251	1·69395	0·87644	0·93435	0·89936	1·02615	49	0·92288	0·01147	48
Males.	50	98·05406	84·18837	165·77701	192·97034	142·44162	1·96108	1·68377	0·67849	0·68777	0·67689	0·997621	49	0·67529	0·01248	48
Sexes Combined.	100	196·17980	168·88590	332·89611	386·41952	286·84935	1·96179	1·68885	1·55595	1·62640	1·57744	1·01381	99	1·59922	0·02718	98
Height of Body at Dorsal Fin																
Females.	50	98·12574	62·79800	124·05348	193·44918	79·70987	1·96251	1·25596	0·87644	0·83810	0·81178	1·03242	49	0·83801	0·00009	48
Males.	50	98·05406	62·84356	123·94273	192·97043	79·81256	1·96108	1·25687	0·67849	0·32633	0·70148	1·01388	49	0·72525	0·10113	48
Sexes Combined.	100	196·17980	125·64156	247·99621	386·41952	159·52243	1·96179	1·25641	1·55595	1·66512	1·51386	0·97295	99	1·47291	0·19221	98
Height of Body at Anal Fin																
Females.	50	98·12574	57·06877	112·83009	193·44918	66·02178	1·96251	1·14137	0·87644	0·88520	0·83206	0·94936	49	0·78992	0·09528	48
Males.	50	98·05406	57·13067	112·78748	192·97034	66·22989	1·96108	1·14261	0·67849	0·95182	0·74967	1·10491	49	0·82832	0·12350	48
Sexes Combined.	100	196·17980	114·19944	225·61757	386·41952	132·25176	1·96179	1·14199	1·55595	1·83705	1·58225	1·06190	99	1·68899	0·22806	98
Length of Head																
Females.	50	98·12574	65·39096	129·18149	193·44918	86·36289	1·96251	1·30782	0·87644	0·84324	0·85108	0·97106	49	0·82645	0·01679	48
Males.	50	98·05406	64·83897	127·80972	192·97034	84·72835	1·96108	1·29673	0·67849	0·64618	0·65531	0·96583	49	0·63292	0·01356	48
Sexes Combined.	100	196·17980	130·22993	256·99121	386·41952	171·09124	1·96179	1·30229	1·55595	1·49411	1·50744	0·96882	99	1·46044	0·03367	99
Length of Snout																
Females.	50	98·12574	44·33322	87·81412	193·44918	40·18488	1·96251	0·88666	0·87644	0·87639	0·80974	0·92389	49	0·74811	0·12828	48
Males.	50	98·05406	43·35246	85·71971	192·97034	38·40118	1·96108	0·86705	0·67849	0·86705	0·69507	1·02443	49	0·71205	0·10078	48
Sexes Combined.	100	196·17980	87·68563	173·52683	386·41952	78·58606	1·96179	0·87685	1·55595	1·69888	1·50594	0·96785	99	1·45752	0·24136	98
Length of Dorsal Spine																
Females.	50	98·12574	52·72025	104·34730	193·44918	56·56546	1·96251	1·05440	0·87644	0·97723	0·88328	1·00780	49	0·89017	0·08706	48
Males.	50	98·05406	53·73367	106·00630	192·97034	59·06119	1·96108	1·07467	0·67849	1·31523	0·63028	0·92894	49	0·58549	0·48918	48
Sexes Combined.	100	196·17980	106·45392	210·35360	386·41952	115·62665	1·96179	1·06454	1·55595	2·302 0	1·51337	0·97263	99	1·47194	0·83026	98

TABLE 5

Tests of Significance for Differences in Values of Regression Co-efficients Between Sexes of *Mystus gulio* (Hamilton)

Variates	Deviations from total average regression		Deviation from individual regressions within samples		Difference		Mean square	Variance ratio (F)	Confidence Level	
	Degree of freedom	Sum of Square	Degrees of freedom	Sum of Square	Degrees of freedom	Sum of Square			5%	1%
Snout to L. H. C. P	99	0·02344	98	0·02334	1	0·00010	0·000238	0·042	3·94	6·90
Snout to Anal Fin	99	0·02718	98	0·02395	1	0·00323	0·000244	13·2377	3·94	6·96
Height of Body at Anal Fin	99	0·19221	98	0·18735	1	0·04869	0·001910	2·54	3·94	6·90
Height at Anal Fin	99	0·22806	98	0·21878	1	0·00928	0·002232	4·15	3·94	6·90
Length of Head	99	0·03367	98	0·03035	1	0·00332	0·000309	10·72	3·94	6·90
Length of Snout	99	0·24136	98	0·22866	1	0·01270	0·002333	5·44	3·94	6·90
Length of Dorsal Spine	99	0·83026	98	0·57624	1	0·25402	0·005884	43·20	3·94	6·90

But length–weight coefficient and the tested 'F' value of 12·8779 between the males and females during spawning show highly significant differences (table 3 and figure 1). Females tend to be heavier and they increase in weight at a much faster rate than the males during or just prior to spawning months. Otherwise both sexes grow apace over the whole year. Sexual dimorphism is hence very apparent in the fish during the breeding season, females being heavier than the males at that time.

Covariance Analysis of Body Part Measurements.—Figures 2 and 3 indicate the resultant scatter diagrams from plotting the log values of body parts against total length on a double logarithmic grid. In all cases, except in length of the maxillary barbel and length of dorsal spine, relationships noted are linear, and straight regression lines can be drawn without hesitation. Only in the above two characters, a perceptible bradyauxesis is apparent, results being somewhat curvilinear. This is true of both sexes and the inflection occurs at a log total length of 1·960 (=91 mm.). Seemingly, both sexes attain a length of 91 mm. (t. l.) quite fast (–the length calculated to be attained in about 9–10 months as described elsewhere) and soon after, is subjected to a slower rate of growth which is reflected in the more sensitive barbels and spines, rather than in body proportions.

In tables 4 and 5 and figures 2, 3 and 4, the statistical data, covering this entire study, are summed up. Dorsal spine also is included for 'F' test, as the females appear to have larger and stronger spines than the males ; (this data from 50 individual in a sample, cannot further be split up without introducing some bias). Each character is described below.

Snout to least height of Caudal Peduncle.—In this character, there is no significant difference between the sexes, 'F' being only 0·420. Appropriate regression line is shown in fig. 1, which clearly indicates that the regression lines overlap.

Distance between Snout and Dorsal Fin.—There is a slight difference in the slope (fig. 4) and the corresponding 'F' has a value of 13·2377 which is significant. The difference is caused by an acceleration in the growth of the female in this character.

Height of Body at Dorsal Fin.—No difference is noted between the sexes in this character, both slopes being parallel. Appropriate 'F' value is only 2·54, much below the significant level of 3·94 at 5%. The test shows that depth of the body in both sexes does not differ very much to enable any distinction between them. (Probably during spawning season some difference may be noticed as the lots now studied are composed of individuals over the whole year).

Height of Body at Anal Fin.—A 'F' value of 4·15 is significant of 5% but not at 1% levels (table 5). In this character male has a faster growth than the female as borne out by the values and the slope 'b' with the positive allometry being exhibited by the male. Probably, the slight swelling and resultant increase in height due to the presence of genital papilla, may have some tendency to increase the width of the body as compared to the female.

Length of Head.—Appropriate 'F' test shows significant differences between the sexes, but such a difference is not evidenced by the slope of the regressions, the reduced sum of squares being the criteria for 'F' test, and generally not the slope.

Length of Snout.— Significant difference is present at 5% level but not at 1%, 'F' being 5·44 (table 5). Snout tends to be more pointed and longer in the male than in the female and grows faster as shown by the regression slope in fig. 4.

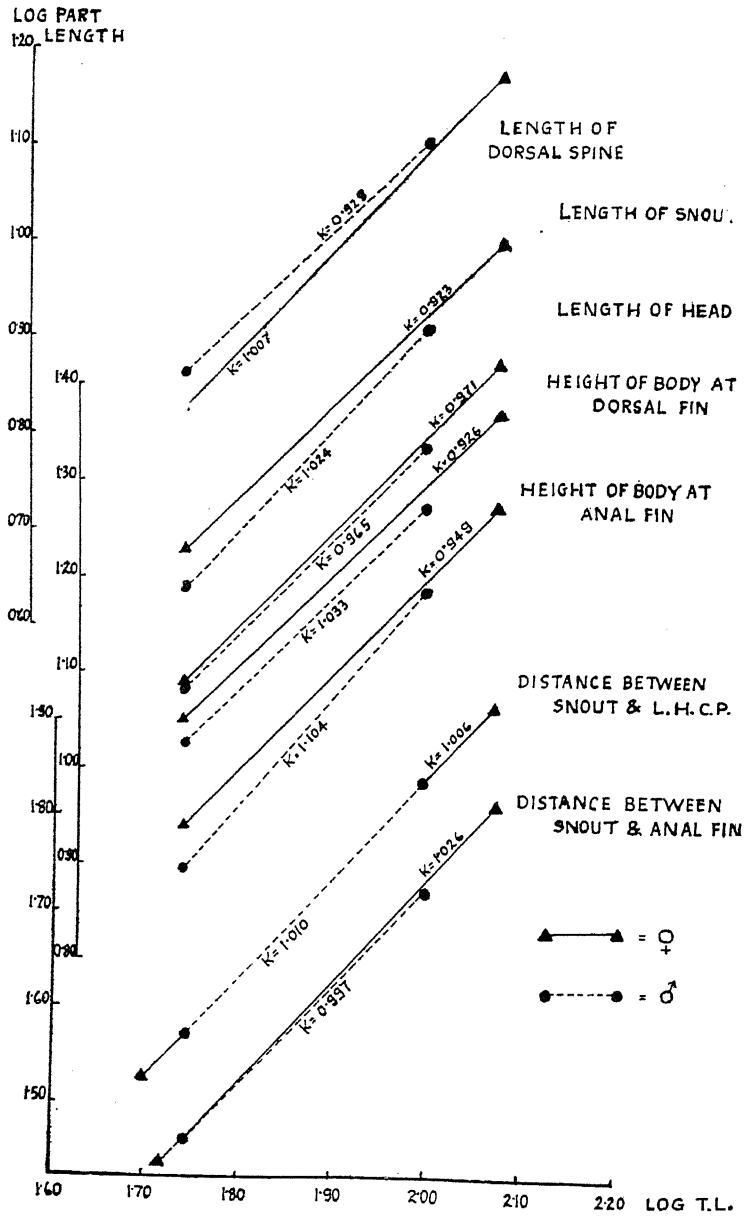

Fig. 4. Regression lines are drawn from equations derived for each tested character in the males and the females. The differences in appropriate 'F' values are noted in some characters even if they do not closely approximate to the slopes ; but in non-parallel lines, such differences are highly significant.

Length of Dorsal Spine.—Females show a sharp tachyauxesis compared to the males over the entire range of measurements. The curvilinear nature of the scatter in this test is disregarded. It is however observed, that females have slightly stronger and larger spines than the males.

In the covariance analysis of body proportions and body part lengths, in spite of significant differences brought out during 'F' tests in most characters, it is difficult to distinguish the sexes in lots otherwise than by the presence or absence of genital papillae. Probably a sharper snout, thin and slightly smaller dorsal spine and relatively larger depths of body at anal fin origin, may serve to a certain extent such separation of males from the famales easier. But in a small fish like *M. gulio* such differences are bound to be very obscure, dependence on the presence of genital papillae being the only external criteria ; otherwise by cutting open the abdomen, structure of gonad can still be used to distinguish the sexes as explained further even in smaller individuals.

Fecundity and Breeding Season :

Ova Development.—During the course of investigations, it was not possible to observe actual breeding and early life, as subsequent to obtaining sufficient material and relevant information, it was not possible for the author to visit locations of spawning during the season. However, it was observed that the females show Ist and IInd stage ova from December and by April most of the females are fully mature with IVth stage ova. By May a sprinkling of spent females in collections from the Kulti and Matlah were noted. By an examination of ova at various stages of growth, a single dominant group was found increasing in diameter, and indicated a peak in individual examples.

In figure 5, some 300 ova diameters of a ripe ovary, where some softened ova were already seen, are represented in a frequency polygon. 0·736 mm. is the mean diameter of ova just prior to exudation, with the range varying between 0·568 and 0·976 mm. (These measurements were made in u—values and converted into millimeters to facilitate reading). 0·064—0·160 mm. diameter ova are present all the year round in mature and maturing specimens. From the evidence of ova diameters with a single peak it is obvious that shedding occurs all at one time in an individual fish.

Fecundity.—During investigations, ovaries from 45 examples exhibiting IVth stage (fully ripe) ova were weighed. The ranges in sizes, weights of fish and the gonads are as follows :

	N = 45	
Range T. L.	=	79–170 mm.
Range in weight	=	4·8–78·0 gms.
Range in weight of ovary	=	0·8–13·4 gms.

Only two specimens amongst the above, were below 100 mm. in total length (97 and 92 mm.) weighing 4·8 and 7·5 gms. in total weight and 0·8 and 1·7 gms. in ovary weights respectively.

It has been possible to establish the following relationships between the wheight of fish and weight of ovaries *i.e* , the gonado-somatic index referring only to the fully ripe unspent examples. The empirical weights were converted into logarithmic weights and treated for the usual regression statistics. The following equation has been derived.

Log Wt. of Ovary = − 0·93878 + 1·9347 × Log. Wt. of Fish.

Further by actual ova counts in 0·5 to 1·1 gms. removed at random from the above ripe ovaries in six examples, it is computed that 1 gm. of ripe ovary contains a mean number of 4149 ova. Transforming this to body weights, 1 gm. of whole fully mature fish yields 801·5 ova. This is unusually a very high rate of fecundity for a catfish.

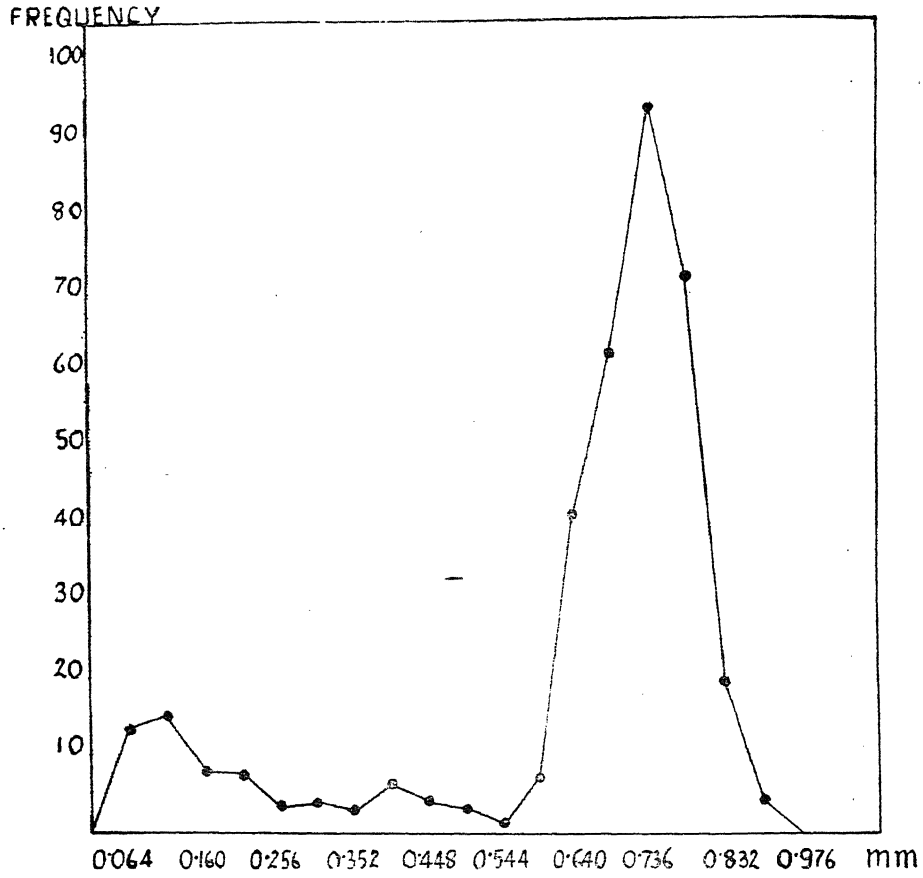

Fig. 5. Ova diameters in mm. plotted for a mature female, indicating a single spawning in an individual during the year.

Left ovary is the longer in all specimens observed. Smallest specimen containing ripe ova (0·8 gm.) was 79 mm. in size and 4·8 gms. in weight. Such precocious examples however appear to be exceptions as ripe females are generally over 100 mm. and 12·5 gms. in length and weight.

Development of Testes.—As small as 41 mm. long (t. l.) *M. gulio* (Hamilton) can be sexed by an examination of preserved specimens. Pattern of development is similar to *Pangasius pangasius* (Hamilton) as described by the author (David *Mss*). Hora and Law (1941*a*) opined that the testes are ribbon like in *Mystus malabaricus* (Jerdon) but such ribbon like appearance soon assumes villi-like projections, which as the spawning season approaches, becomes tubular and highly turgid. In milting

males, both tubular chambers or lobules of the testes and the genital papillae, become highly swollen and appear almost similar to those in *P. pangasius*.

Breeding.—Actual spawning of this species has not been observed, but milting males and oozing females have freely occurred in catches at flow tide currents in June and July, when they enter low lying fresh water tracts adjoining the estuaries where fresh water drains into the estuaries. Though rains facilitate such movements, heavy rains do not appear strictly necessary, as even in April and May months, with the sporadic 'North Westers' common over the deltaic Bengal, some isolated spawning appears to take place as evidenced by some spent adults at the time.

The species schools in large numbers ; as in the case of most fish whose fecundity is high, no parental care is observed. [*Cf.* Raj, 1941 in *M.* (=*Aoria*) *aor* and *M.* (=*Aoria*) *seenghala*]. No larval stages or fry are obtainable from the estuaries proper at any time. 6–8 weeks old fry which grow to 24–30 mm. (t. l.) in the inundated low lying fresh water tracts, enter the estuaries in large numbers from September—October months as the water is drained off, when it is possible to collect them in numbers from the narrow channel mouths, or isolated but fast drying fresh water pools close to estuaries in lower Bengal.

There is no description of early embryos or even larval stages of this important species or even the Genus *Mystus**. From half a dozen or so, bluish green eggs collected and resultant studyand rearing of the larvae at Balawali on the Ganga river in August, 1955, and their proving to be a *Mystus*, it is highly probable that *Mystus gulio* too may have a prolonged hatching and developing period than most other catfish families, and the embryo may possess a linear (not rounded or pear shaped) yolk sac, which gets absorbed only slowly over a period of 8 to 10 days. It is possible that the larvae sink to the shallow bottom, as they have never been obtained from surface plankton.

The females outnumber the males in catches by 10–38% between April and July, later in September—October, spent females are found 60–100% in numbers more than the males. But in November—December, 20–40% more males are again noticed in the catches.

Growth in Length :

It fig. 6 the frequency polygon of total lengths of *M. gulio* obtained from the combined Matlah and Kulti estuaries are presented. Trend shows that there is a continuous recruitment of young from August ceasing only in December. This more or less confirms that spawning should have occurred in May to August for such recruitment to be possible. The connected peaks between October and December and January and May, indicate a length increase of 20 mm. in *two* and 50 mm. in *four* months respectively. It is highly plausible that 30–40 mm. (t. l.) examples could be three to four months old. In about ten months, from July to May, majority of the specimens can attain a size of 90 to 110 mm. (t. l.). Even though some of them can mature quite early (at 70–80 mm. in females and only 50–60 mm. in males), majority start spawning between 90 and 100 mm. (t. l.). It is noted already that there is a negative allometry (bradyauxesis) at about 91 mm. in both the male and female examples. This may indicate that after an initial fast growth upto 91 mm. or so from birth, and attainment of maturity within ten months, the fish is subjected to a retardation in growth, the 0–1 year onwards, growth being much slower.

* Sri B. N. Saigal of this Sub-Station has succeeded in collecting embryonic eggs, larval stages and fry of *M. aor* and *M. seenghala* recently, the record being the first known in any *Mystus*.

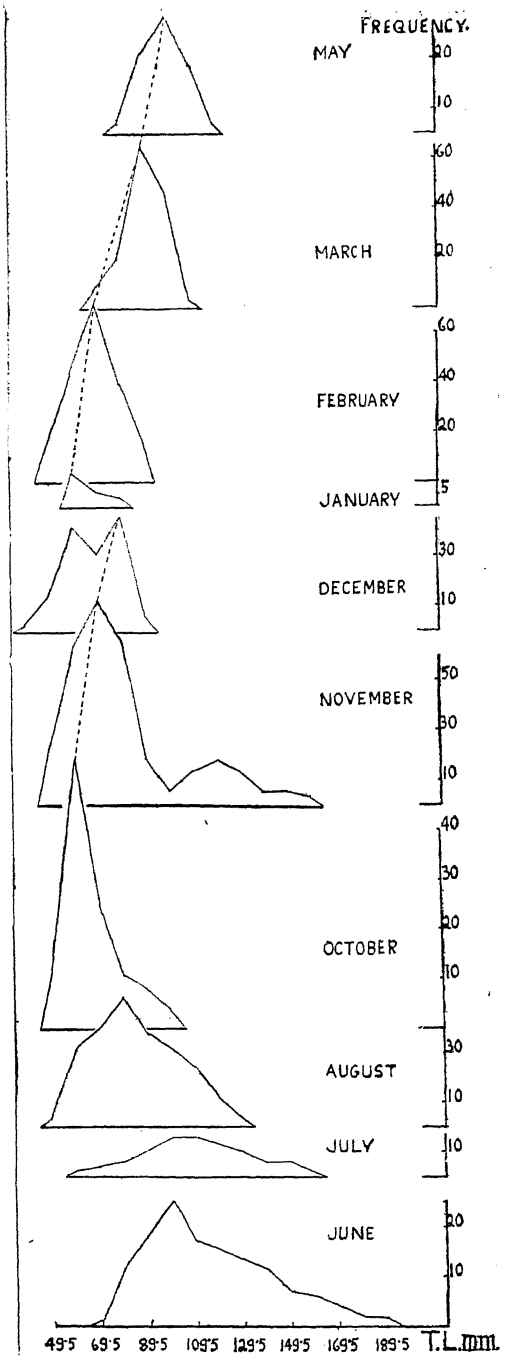

Fig. 6. Frequency polygons indicating trends in growth increments and recruitment in *M. gulio*. A growth rate close to 10·00 mm. per month is calculated. Recruitment is prolonged in keeping with an extended spawning period.

Lack of sufficient material in higher ranges in author's present collection renders observations on growth or surmised age difficult. Since almost all available stock entering or leaving fresh waters are eventually caught by efficient fishing during spawning movements within the narrower channel entrances by fixed traps and nets, few specimens seem to escape for starting the cycle afresh in the ensuing year. Hence it is not common to observe specimens of over 160 to 170 mm. (t. l.) for studying the growth and food, in the open estuaries.

Condition Coefficient.—The table 6 presents the ponderal index or K-factor from mixed samples at Port Canning and Kulti, over a 12 months period. Though it is not correct to combine the two estuaries for such a study, at least some information on relative robustness of the fish, can be gathered over 12 months from month to month. Number and weight—and size ranges are also given.

TABLE 6

Coefficient of condition in *M. gulio* (Hamilton) month to month (sexes combined)

Months	No.	Size Range (mm).	Weight Range (gms.)	Coefficient of condition
June	50	74–184	3–80	1·0262
July	25	58–161	2–45	1·0686
August	38	52–129	2–29	1·1034
September*	–	–	–	–
October	37	59–156	2–43	0·9971
November	35	61–128	3–35	1·2227
December	35	104–164	10–45	0·9686
January	14	54–80	2–7	1·0364
February	31	55–135	2–31	1·1853
March	21	82–104	6–11	1·0132
April	22	46–102	1–13	1·3227
May	22	82–119	5–14	0·8259

*No collections were made in September.

Due to intermixing of sizes and of regions, a continuous picture of fluctuations does not seem to emerge In a tidal area the stock available at any place at each tide, may originate at different regions. Due to schooling habits of the fish in tidal estuaries over long distances and unrepresentative sizes due to peculiarities of fishing methods, biases have crept into the above data. Nevertheless K-values do not deem to fluctuate very greately as spent and unspent specimens are found together in breeding months and small as well as big specimens are intermixed at all other times.

TABLE 7

Analysis of Various Categories of Food Items Expressed as Percentage of Volume in *Mystus gulio* (Hamilton)

Months	Matlah at Port Canning									Kulti						
	June 1954	Aug. 1954	Oct. 1954	Nov. 1954	Dec. 1954	Jan. 1955	Mar. 1955	Nov. 1955	Dec. 1955	Jul. 1954	Aug. 1954	Oct. 1954	Mar. 1955	Apr. 1955	May 1955	Sept. 1955
No. of specimens examined	28	25	30	27	40	15	30	35	40	40	49	37	27	40	30	8
Range in size (mm.)	79–184	60–116	54–146	48–92	48–79	54–84	66–104			59–161	72–122	59–130	54–97	55–71	86–111	83–103
No. of specimens with empty guts	9	–	3	–	–	1	–	–	1	6	6	2	11	5	2	–
Percentage containing food	67·85	100·00	90·00	100·00	100·00	93·33	100·00	100·00	97·50	85·00	81·63	94·59	59·26	87 50	93·33	100·00
Volume of food (cc) (Total)	–	4·7	10·7	18·1	7·15	1·00	5·5	24·65	–	–	8·3	10·2	0·7	0·1	–	–
Volume of food per fish (cc)	–	0·18	0·39	0·67	0·18	0·07	0·18	0·70	–	–	0·19	0·27	0·04	–	–	–
Protozoa ...	–	–	–	–	–	0·28	–	–	–	–	–	–	–	0·57	–	–
Polychaetes ...	0·10	–	–	–	–	0·10	1·00	0·14	–	0·73	8·14	5·95	–	–	–	–
Molluscs ...	–	–	4·44	–	–	0·35	–	0·71	–	–	–	–	–	–	–	9·37
Crabs ...	–	2·16	4·52	0·55	1·25	0·14	2·00	3·91	–	1·29	9·69	2·03	–	–	–	–
Prawns ...	26·31	3·80	–	10·74	5·50	12·50	28·33	22·88	31·07	0·26	5·00	12·16	5·62	–	–	–
Amphipods, Mysids and Isopods	–	–	0·81	61·11	8·80	0·35	0·50	0·14	–	–	12·44	4·64	–	–	–	–
Megalopa ...	–	–	–	–	0·12	2·14	0·16	–	–	–	2·91	–	–	–	–	–
Entomostraca ...	–	2·60	2·96	–	–	0·35	8·00	–	–	0·12	4·16	2·61	1·81	2·85	1·03	2·12
Insects ...	–	0·68	3·22	7·37	6·05	0 64	5·00	0·20	0·25	1·41	4·30	10·94	2·81	1·20	–	2·50
Fish ...	–	16·60	11·48	2·41	7·92	0·64	5·30	8·20	11·28	0·06	0·58	–	1·56	0·43	0·61	39·38
Algae, Diatoms and Vascular Plants	–	12·56	0·96	–	0·62	–	–	0·57	0·89	–	2·67	0·54	2·06	1·00	–	1·12
Excreta ...	–	4·00	0·55	–	–	–	–	–	–	–	–	–	–	–	–	19 37
Mud and Sand ...	–	–	–	–	–	–	–	0·17	1·56	1·47	–	–	0·31	–	–	–
Miscellaneous ...	–	–	1·49	–	–	–	–	–	–	–	–	–	–	–	–	–
Unidentified ...	–	–	1·85	–	–	–	–	–	1·54	–	–	3·10	0·98	–	–	–
Digested Matter ...	2·21	9·16	20·85	0·18	–	3·85	2·36	1·17	2·48	1·73	11·48	8·51	3·18	4·82	5·25	–

TABLE 8

Analysis of Various Categories of Food Items Expressed as Percentages of Occurrence in *Mystus gulio* (Hamilton)

	Matlah at Port Canning											Kulti								
	June 1954	Aug. 1954	Oct. 1954	Nov. 1954	Dec. 1954	Jan. 1955	Mar. 1955	Nov. 1955	Dce. 1955	Total Aver. % Vol.	% Occur	Jul. 1954	Aug. 1954	Oct. 1954	Mar. 1955	Apr. 1955	May 1955	Sep. 1955	Total Aver. % Vol.	% Occur.
Protozoa	...	...	...	...	...	14·28	...	...	...	**00·3**	**1·58**	...	...	...	...	2·85	..	...	**0·08**	**0·41**
Polychaetes	5·26	...	...	...	...	7·14	66·66	2·85	...	**0·15**	**9·10**	8·82	13·97	10·81	...	...	...	...	**2·11**	**4·79**
Molluscs	...	...	14·81	...	...	7·14	...	2·85	...	**0·61**	**2·75**	...	...	...	...	...	...	12 50	**1 33**	**1·78**
Crabs	...	20·00	14·81	3·70	2·50	7·14	20·00	20·00	...	**1·61**	**9·79**	17 64	44·18	2·70	...	...	...	...	**1·85**	**9·21**
Prawns and Acetes	5·26	20·00	...	25·92	12·50	21·42	23·33	77·14	61·53	**15·68**	**27·45**	2·94	20·94	48·64	18·75	...	...	...	**3 29**	**13·03**
Amphipods, Mysidaceae and Isopods	...	...	11·11	96·28	70·00	7·14	3·33	2·85	...	**10·19**	**21·19**	...	34·88	13·51	...	...	...	...	**2·44**	**6·91**
Megalopa	...	...	...	...	2·50	...	3·33	...	...	**0·03**	**0·64**	...	2·32	...	...	...	...	...	**0·42**	**0·33**
Entomostraca	...	12·00	11·11	...	...	42·85	46·67	...	...	**1·74**	**12·51**	5 88	13·95	16·21	43·75	5·71	14·28	25·00	**2·10**	**17·82**
Insects	...	8·00	11·11	29·63	20·00	7·14	6·66	5·71	5·13	**2·56**	**10·37**	23·53	25·58	37·83	31·25	14·28	...	25·00	**3·31**	**22·49**
Fish	...	36·00	22·22	7·40	22·50	21·42	16·66	22·85	23·07	**7·09**	**19·12**	5·88	2·32	...	6·25	2·85	14·28	62·50	**6·08**	**13·44**
Algae, Diatoms and Vascular Plants	...	52·01	18·52	...	2·50	21·42	...	5·71	5·13	**1·80**	**11 69**	...	13·95	2 70	43·75	25·71	...	37·50	**1·05**	**17·65**
Excreta	...	8 00	3·70	...	...	...	...	...	...	**0·50**	**1·30**	...	...	...	...	...	...	62·50	**2·76**	**8·92**
Mud and Sand	...	...	...	...	...	...	...	8·57	25·64	**0·19**	**3·80**	2 94	...	...	6 25	...	...	...	**0·25**	**1·31**
Miscellaneous	...	...	14·81	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Unidentified	...	...	3·70	...	...	...	...	...	20·51	...	...	...	...	...	...	...	...	...	...	...
Digested matter	78·94	72·00	70·37	3·70	...	71·42	46·67	37·14	17·94	**4·62**	**44·24**	58 88	55·81	45·94	75·00	80·00	100·00	...	**4·99**	**59·38**

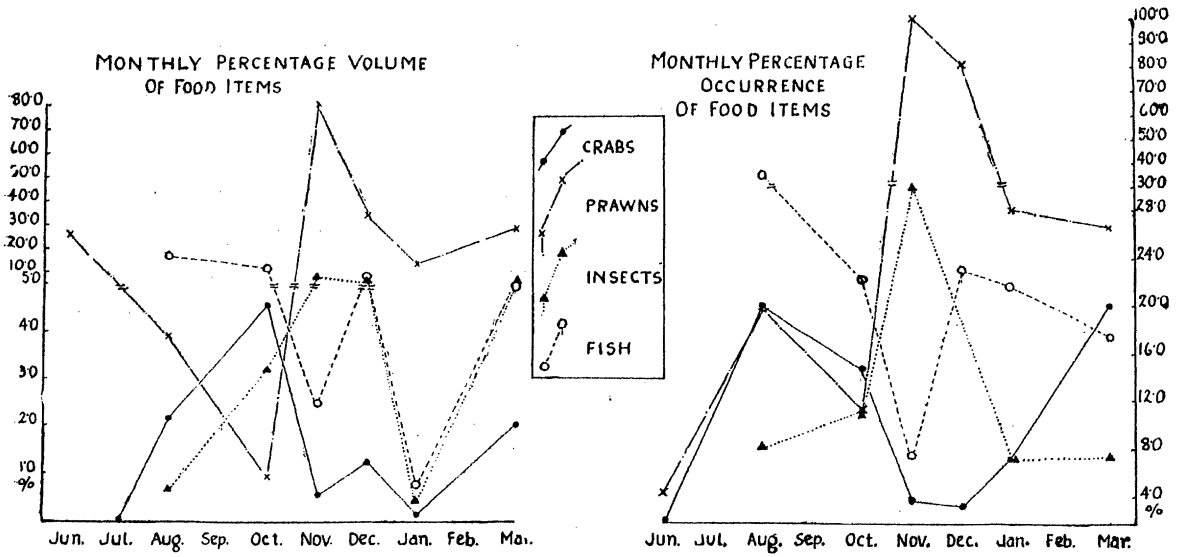

Fig. 7. Monthly percentage of occurrence and volume in food items in *M. gulio*, shown by frequency polygons for the Matlah samples. Scales in upper ranges are accelerated.

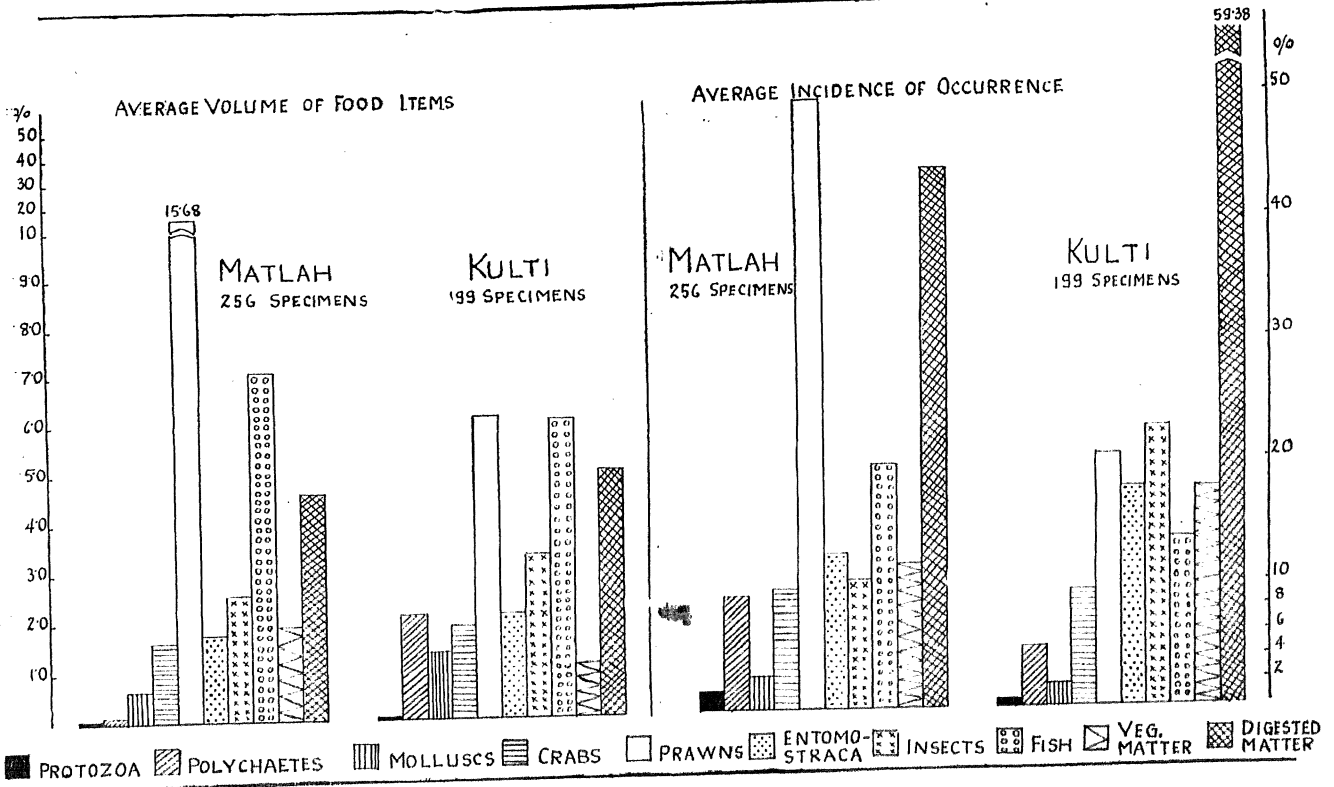

Fig. 8. Histograms representing average food items noted for the Matlah and Kulti samples. Percentage volumes and percentage occurrence bring out the proclivities of the fish to feed not only upon Crustaceans—Prawns and Crabs, but Fish also which form considerable proportion (ranked second) of such food ingested.

Food Habits :

Food items noted in this species from the Matlah and Kulti estuaries are shown in tables 7 and 8 both volumetrically and by occurrence, along with the number of examples studied, their size ranges and such relevant information. In fig. 7. the frequency polygons for observed monthly percentages of food between June and March for Matlah lots, is shown. In fig. 8, average values for the entire period observed in both regions, are represented by both methods in histograms.

Maximum amount of food noted in the fish was during November in the Matlah and October in the Kulti lots. (Volume per c.c.). Almost no food was found during June—July and August months. The fish is omnivorous at the size ranges studied, not being disinclined towards any available organic food. Food items range from Protozoans to fish, and Diatoms to Vascular plant tissues and Fruits. Its propensity to feed upon other fish is fully developed, but probably is limited by its small size. Molluscs do not form an important item of diet for similar reasons.

Protozoa :

Protozoans formed only 0 28 and 0·57% respectively in January and April at Port Canning and at Kulti. Identified organisms consisted mostly of *Difflugia* and *Arcella.* Otherwise this was an insignificant group in the fish.

Polychaetes :

Polychaetes were more in evidence by volume in the Kulti examples rather than in the Matlah, where occurrence frequency was higher (table 8).

Molluscs :

Molluscs do not from a major item of food in *M. gulio.* A volume of 0·61 to 1·33% and occurrence of 1·78 to 2·75% is insignificant. In confined ponds, probably the fish feeds better on Molluscs (Pearse, 1932) due to availability, but then too, only small shells are ingested by the fish. Items of Molluscs identified are small *Stenothyra* and *Bythinia* species.

Crabs :

Dismembered chelate and other swimming legs of crabs are referable to this group, with rarely any whole crabs. An occurrence of 9·79 and 9·21% as against 1·61 and 1·85% volume, brings out this fact well. *Varuna litterata* and *Scylla serrata,* two swimming crabs appear to be the species involved.

Prawns :

This group includes Prawns, Amphipods, Mysids, Isopods and Megalopa of crabs, all of which being somewhat *soft shelled,* become an unidentifiable mass in the guts 25·90 and 6·25% by volume and 49·28 and 20·27% by occurrence of all food items over the period of study in the Matlah and the Kulti respectively, are referable to this 'Prawns' group. *Penaeus, Leander* and *Metapenaeus* amongst larger Crustacea dominated this category. Megalopa larvae of swimming crabs were found mostly in July and August months, those of *Varuna litterata* being prominent. Amphipods (*Gammarus* spp.), *Sagitta* spp., Mysids—*Macropsis orientalis* and some Isopods were recorded commonly. Low numbers and volumes of all these items in the Kulti estuary is difinitely attributable to their nonavailability. Most of them are killed by sewage pollution as compared to their higher percentage occurrence and the volume in normal Matlah estuary. It is evident that this fish at least in its natural environment, prefers to feed selectively upon soft shelled Decapodans and other related smaller Macro-crustaceans. It is also further noted that intensity of feeding upon this 'Prawn' group was generally high in November and December

months. This category is found to form the dominant food item of *M. gulio* over the enitre period.

Entomostraca :

Micro-crustaceans were well represented in this small catfish even though the fish were fully grown in some cases. Copepods of which *Diaptomus* spp. dominated, constitute the richest plankton of all deltaic Bengal estuaries and tidal waters. Cladocerans were represented only by *Liptodora* spp. which occurred occasionally. Ostracods were recognised as stray items during mansoon months. Even though percentage occurrence was 42·67 to 46·67 during January and March in the Matlah, the volume percentage of Entomostraca was only 0·3 to 8·8, never forming the bulk of the food. Average value of 1·74 and 2·10% by volume and 12·5 and 17·82% by occurrence in the Matlah and Kulti estuaries, are by no means, therefore surprising.

Insects :

Both terrestrial and aquatic Insects formed upto 29·00 and 37·83% in the Matlah and Kulti estuaries by volume in November, which also coincided with the period of intense feeding activity of the fish. Average volumes of 2·56 and 3·31% by volume and 10·37 and 22·49% by occurrence over the period, have been computed. Insect group represented mainly small ants and similar insects. A natural scarcity of all Insects in estuaries most probably accounts for a lower percentage of ingestion as already noted by the author (David, *Mss.*) in *Pangasius pangasius* (Hamilton).

Fish :

Other fish entered the diet of *M. gulio* liberally from 7·40 to 36·00% occurrences (average 19·12%) and between 0·64 to 16·60% by volume (average 7·09%) in the Matlah estuary. Mean 6·08% by volume and 13·44% by occurrence are recorded in the Kulti, whole fish species noted in its diet consisting of small *Hemiramphus* spp. and *Puntius* spp. But total percentage recorded mostly are due to fish scales (ctenoid), fish heads, or vertebral bones all of which might probably be included under "Offal" group as in *Pangasius pangasius*. *Mystus gulio* is too small in the observed sizes to be included under mainly a predaceous group of fishes, but otherwise Teleosteans contributed the second largest item of food ingested by this fish next only to "Prawns".

Vegetable Matter :

Algae (free living and filamentous), Diatoms, Vascular Plant Matters and Sponges were prevalent 11·69 and 17·65% respectively in the Matlah and the Kutli samples. *Oscillatoria, Nitzschia, Coscinodiscus* and soft half digested vascular tissues and sponge spicules have been commonly identified in the gut. Algal matter alone constituted 52·01% in occurrence (only 12·50% by volume) in August from the Matlah ; presence of these varied vegetations, fully brings out the omnivorous nature of feeding in this fish. Appearance of plankton items such as *Nitzschia, Coscinodiscus* etc. further confirms that the fish voluntarily feeds upon such phytoplankton items, as well as zoo-plankton earlier mentioned, and it is not merely chance that such items constituted its diet.

Offal :

Cow or buffalo dung and faecal matter do form food of this fish as noted to an extent of 62·50% by prevalence and 19.37% by volume at least in one lot in the

Kulti estuary in September, 1956. The fish is not averse to foul smelling environments as, in spite of deoxygenation it is continually found in the sewage polluted Kulti.

Mud and Sand :

Mud or sand were indicated in the lots examined generally when some Algae were also present, showing that probably these items were taken together.

Micellaneous :

Rotifers, Insect Eggs, Debris of all kinds, Pulses, Seeds, (*Oriza sativa*) etc., have been observed in the gut. Most of them appear to be chance entrants rather than due to propensity on the part of the fish to seek such food.

Digested Matter :

Digested matter never formed more than 5·0% by volume either in the Matlah or the Kulti lots. But an occurrence of 100% digested matter has been noted at least once. The fish is never found free from food, as the intestine invariably contained some digested matter. Even in June—July, traces of Digested Matter with Insect remains is found, showing some amount of feeding by the fish even during its spawning months. Nearly 75% of the examined fish guts contained living Nematode worms ranging from two to twenty-eight in numbers.

Remarks :

Knowledge regarding any *Mystus* is lacking with reference to its biology. *Mystus gulio* being a fish of such a wide distribution, present preliminary studies, may serve as a basis for more detailed studies elsewhere. Fishery value of this fish both in its captural and cultivated environments are too well known to be further elucidated. A good deal is still to be known about its early life history and growth in salt water 'bheris' as compared with natural environments.

Sexual dimorphism in the sexes now discussed may not serve any immediate need of the fishery, but the data presented may throw some light on segregation of populations from delta to delta in India and elsewhere.

Pillay (1954) records some food items of this fish in a brackish culture pond, where the dominant categories of food eaten were Detritus, Copepods, Plant matter, Decapodon Crustacea, Prawns and Fish in the order mentioned volumetrically, Prawns and Copepods formed 50% by occurrence. But the above findings as well as those or Chacko (1947) are for fish confined to stagnant waters. Conditions being widely different in the tidal estuaries subjected as they are to constantly moving fast tidal currents, where deposition of organic Detritus and Filamentous Algae are scarcely encouraged due to shifting bottom, fish in the 'bheris' appear to feed differently from those of the estuaries.

The only comparable species is *Pangasius pangasius* (Hamilton) which has certain common traits with *M. gulio* in feeding. Crustaceans, Insects, and Vascular plants, form common items of food in both species, offal being however, very dominant in *P. pangasius* (David *Mss.*). But hardly any protozoans or Entomostracans enter into *P. pangasius* as an important item of diet. Regarding a Fish diet even at smaller sizes, *M. gulio* is difinitely predaceous, but Molluscs probably do not enter its diet freely as the shells might prove too big and beds where they are found are also scarce in the Bengal estuaries. Nevertheless, nothing is definitely known about its Molluscan feeding propensities in fresh water ponds. Unless

larger sizes are examined and species experimentally grown in ponds, nothing difinite can be said at present. *M. gulio* is equally at home in fresh water conditions where it appears to grow well and can also reproduce. There is no reason why it should not also be tried to control Molluscan population, as it may well feed upon the larger shells as it grows in size.

Summary :

Mystus gulio (Hamilton), the small estuarine Bagrid catfish distributed all along the coast line from Java to West Pakistan has been studied for sexual dimorphism, fecundity and food. Sexual dimorphism has been tested in length-weight relationships between sexes over the whole year and during spawning months. Appropriate 'F' tests indicate significant differences during spawning months and not over the whole year. Similarly, analysis of covariance indicates significant differences in distance between snout and dorsal fin origin, height of body at anal fin, length of head, length of snout, and dorsal spine. It is, however, not possible to easily distinguish the sexes by the above characters, but the presence of genital papillae only during or close to breeding months in the males, and the lobulated or villi-like tubules in the testes even in as small as 37 mm. of fish can still serve sexing easy. The fish is prolific, yielding small ova (mean diameter 0·736 mm) of as many as 4149 per gm. wt. of ovary or 801·5 per gm. weight of fish. It spawns in fresh waters adjoining the estuaries between May and September. A growth rate of nearly 10 mm. per month has been computed with attainment of maturity and subsequent first breeding in about 10 months of its life. Lack of larger sizes in the fishery is attributed to the easy vulnerability to fishing of the fish while moving from estuaries to fresh water inundations and *vice versa*.

The fish is omnivorous, with 'Prawns' dominating, followed by Fish items. Vegetable Matter, Insects, Polychaetes, Entomostraca and Offal formed other less important food categories eaten by the fish in its natural estuarine environment. Even though some minute Molluscs were found in the diet, the fish being too small is probably unable to ingest larger sized shells. The species is easily adaptable from a high saline to fresh water conditions and can subsist even in polluted water where deficiency of oxygen is noted. Hence its wide range of distribution and occurrence.

Acknowledgments :

Sri K. H. Sujansinghani, recommended all the statistical treatment in this contribution at each step, but for whose help the data otherwise collected could not have been utilised properly and for all the help rendered the author is deeply indebted to him. Sarvasri J. N. Biswas, Pratap Narain, B. L. Singh assisted the author variously in examination of collections, length-weight measurements, gut studies, tabulation of data for statistical treatment etc. and for all very useful help, the author is thankful to them. Sri S. M. Bhowmick, examined 120 guts in author's collections and made available to the author results for which credit is due to him. Dr. V. G. Jhingran facilitated publication of the paper by meticulously reading through the manuscript and suggesting improvments for which the author is indebted to him.

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PATHOLOGICAL STUDIES OF COLLETOTRICHUM GLOEOSPORIOIDES PENZ. CAUSING LEAF SPOT DISEASE OF PRUNUS PERSICA STOKES.

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(Received on July 17, 1962)

Introduction :

Colletotrichum is a widely distributed plant pathogen. It has been reported to cause severe losses of fruits in storage as well as in orchards. It is also responsible for causing leaf spot and other diseases of numerous economically important plants.

Colletotrichum antramentarium causes ripe fruit rot of tomatoes ; *C. hibisci* is responsible for kenaf anthracnose of *Hibiscus cannabinus* and *C. lindemuthianum* of potato, *Phaseolus vulgaris*, *Dolichos lablab* etc. A leaf spot disease of guinea corn (*Sorghum*) is induced by *C. graminicola* and various sugar cane varieties are attacked by *C. falcatum*. *C. lagenarium* is widespread on melons and water-melons ; *C. gloeosporioides* is a common parasite of leaves, twigs and fruits of species of Citrus. It has also been reported from other plants *viz.*, lime (Fawcett, 1936), papaya (Mitter and Tandon, 1930), mango (Sattar and Malik, 1939 ; Mallik and Hasan, 1959), *Dioscorea alata* L. (Prasad and Singh, 1960), *Anona reticulata* (Chawdhury, 1947), *Polyscias balfuriana* (Chaturvedi, 1961), *Punica granatum* (Chandra, 1961), etc. Many other species of *Colletotrichum* pathogenic on plants have also been reported.

Saccas (1959) reported a very heavy defoliation of young leaves of *Hevea* due to anthracnose, usually attributed to *Colletotrichum heveae* and *Gloeosporium alborubrum*. He further noticed that in moist weather numerous acervuli of *Gloeosporium* type were developed on necrotic lesions, whereas acervuli of *Colletotrichum* type were dominant in less rainy periods. This shows that only one species was implicated.

So far there is no report of any species of *Gloeosporium* or *Colletotrichum* responsible for the leaf spot disease on *Prunus persica* Stokes. It was, therefore, decided to undertake a detailed physiological and pathological investigation of *Colletotrichum gloeosporioides* Penz. isolated from leaf spot of *Prunus persica*. The present paper includes the results of the pathological studies only.

Material and Methods :

Colletotrichum gloeosporioides Penz was isolated from the infected leaves of *Prunus persica* Stokes and a pure single spore culture was obtained with the help of dummy cutter objective. Artificial inoculations were tried on various parts of plants. Both the injured and uninjured portions were used for this purpose. Controls were maintained under identical conditions.

In order to remove foreign material, the operational areas of the plant were first washed with sterilized distilled water. They were then cleansed with 90% alcohol so as to disinfect the inoculatory surface.

The following methods were used for inoculations on the leaves and stems.

1. By spraying spore suspension.
2. By mass inoculations.
3. By sprinkling powder of infected leaves.
4. By keeping infected leaves in contact with healthy ones.

Ridgway's "Color standards and color nomenclature" (1912) was used for determining the colours of the infected parts.

Observations :

A. Symptoms :

(*i*) *Symptoms on leaves. Colletotrichum gloeosporioides* develops several irregularly distributed minute cream coloured spots lined by red margins on lamina of peach leaves. The spots may be circular or irregular in outline. With the advance of the disease the spots finally change to ferruginous colour. Ultimately the lesions become dry papery and brittle and fall off, leaving a 'shot-hole' in the leaf. Under humid conditions several small lesions may coalesce to produce a big infected patch. Occasionally the infection travels inwards from the margin or downwards from the tip.

(*ii*) *Symptoms on twigs.* The disease appears as small red spots which gradually increase in size and finally the lesions become oval in shape with ferruginous outer zone and yellow central zone. In all cases fruiting bodies appear in the centre A gummy secretion oozes out from severely infected regions (vide plate I, Fig. 2).

B. Morphological Nature of the fungus :

No setae were formed in the acervulus at the time of isolation from the host, but they appeared on certain media. Ikata (1936) and Ramakrishnan (1941 observed that setae should be considered of little importance for the purpose of differentiation of species. Their presence was, however, dependent on the kind of substratum used. Setae when present, were septate, thick walled, olive gray in colour, unbranched, broader at the base and tapering towards the apex (vide Plate I, Fig. 3). Acervuli were brown to black.

The conidia were hyaline and slightly rounded at both the ends with one or two oil globules. Their size varied from 7·2 to 19 2 by 2·4 to 4·8μ.

Appressoria of various shapes and sizes were commonly produced.

C. Artificial inoculations :

The organism was inoculated by different methods. The results are summarised in Table 1.

The results of Table 1 clearly show that the disease invariably appeared when injured leaves were inoculated by the mass inoculation and spore suspension methods. The fungus was able to infect uninjured leaves from their lower surfaces. There was no marked difference in the appearance of the disease when inoculations were made by mass or spore suspension methods. The fungus was also able to infect injured and uninjured (lower surface) leaves over which the powder of diseased leaves was sprinkled. There was no infection in any case on uninjured upper surface of the leaves. The percentage infection was greater in injured leaves (Plate I, Fig. 1). All the controls remained healthy.

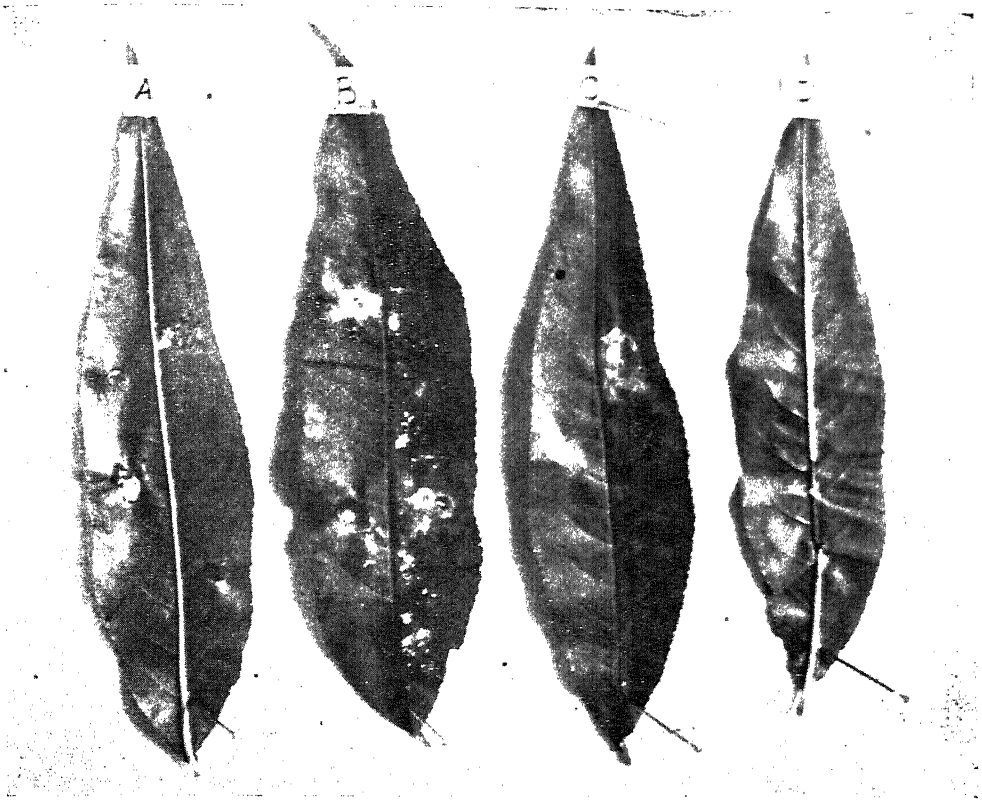

Fig. 1. Infected leaves.
A. inoculated by making injury on upper surface.
B. inoculated by making injury on lower surface.
C. inoculated without injury on lower surface.
D. inoculated after injury on lower mid rib.

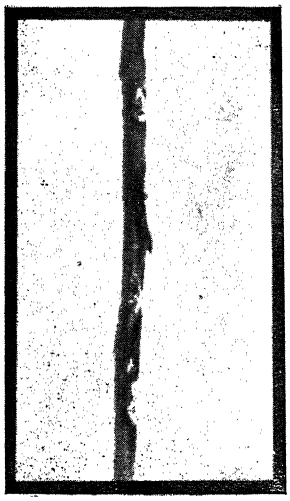

Fig. 2. Infected twig

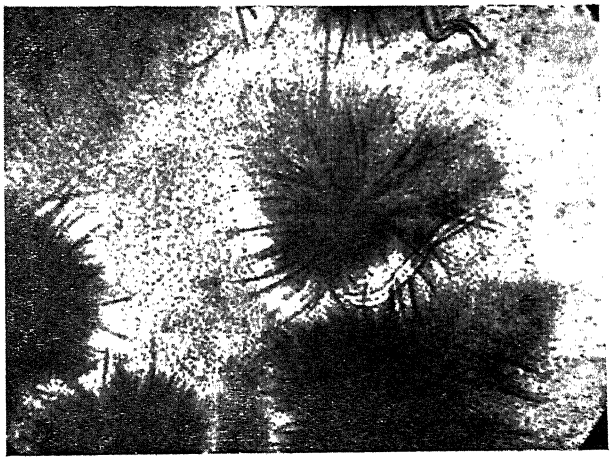

Fig. 3. Microphotograph of the fungus, showing spores and setae X250.

TABLE 1

Showing percentage of infection of peach leaves inoculated by different methods.

Type of inoculum	Condition of leaf	Surface of leaf	Number of inoculations	Percentage of infection
Mass inoculation	Injured	Lower	200	100
	Uninjured	Lower	,,	80
	Injured	Upper	,,	100
	Uninjured	Upper	,,	0
Spore suspension	Injured	Lower	100	100
	Uninjured	Lower	,,	60
	Injured	Upper	,,	100
	Uninjured	Upper	,,	0
Sprinkling of powder of infected leaves	Injured	Lower	,,	100
	Uninjured	Lower	,,	50
	Injured	Upper	,,	80
	Uninjured	Upper	,,	0
Infected leaves tied to healthy ones	Uninjured	Lower	,,	20
	Uninjured	Upper	,,	0

Fifty controls were maintained for each series and they remained healthy.

The stems were also inoculated and it was observed that injured young stems were always infected when the inoculations were made by mass inoculation or spore suspension methods. Under natural conditions, the disease appeared on the stems near the leaf scars of fallen leaves. There was no infection in the controls.

D. Cross inoculations :

The organism was inoculated on the leaves of *Carissa carandas*, *Artocarpus integrifolia*, *Carica papaya*, *Bauhinia variegata*, *Citrus aurantifolia*, *C. medica limonum*, *C. limettioides*, *Capsicum annuum*, *Saccharum officinarum*, *Mangifera indica*, *Psidium guajava*, *Gossypium neglectum*, *Clerodendron thompsonae*, *Pothos scandens*, *Hibiscus rosa-sinensis*, *Grewia asiatica* and *Dracaena angustifolia*.

It could cause infection on *Carissa carandas*, *Artocarpus integrifolia*, *Bauhinia variegata*, *Citrus limettioides*, *Mangifera indica*, *Psidium guajava*, *Gossypium neglectum*, *Pothos scandens* and *Grewia asiatica*.

Reisolations from such infected leaves invariably gave *Colletotrichum gloeosporioides*.

D. Control Measures :

For this purpose a laboratory evaluation of various fungicides was conducted by the method described by Forsberg (1949).

Micop W. 50 (Copper chloride), Kirti copper (Copper chloride), Cupravit (copper oxychloride), Blitox (Copper oxychloride), Copper Sandoz (Cuprous oxide), Cupramar (Cuprous oxide), Diathane Z-78 (Zinc ethylenebisdithiocarbamate), Flit 406 [n- (trichloromethyl mercapto) -4-cyclohexene-1, 2-dicarboximide], Onyxide 75% (mixture of alkenyl dimethyl ethyl bromides), U. N. R. 50% (alkyl dimethyl benzyl ammonium chloride) and Isothan Q-15 (2-dodecylisoquinolinium bromide).

Out of these 25% Flit 406 prevented the growth of the organism. In other cases the fungicides were either ineffective (*viz.*, Micop W. 50, Copper Sandoz, Cupravit, Diathane and Blitox) or they killed the fungus at concentrations which were unsuitable for the host plant (*viz.*, 100% Kirti copper, 100% Cupramar, 10% Onyxide ; 10% Isothan Q-15, and 5% U. N. R.). Flit 406 was, therefore, used for field trials.

The fungicide was applied at different times before and after inoculations. It was observed that the disease was not completely checked under any condition except when the fungicide was applied just before or just after inoculation. The infection was extremely small when the fungicide was applied within 48 hours before or after inoculations. The control regions where the fungicides were not applied developed large diseased spots.

Discussion :

The results clearly show that *Colletotrichum gloeosporioides* Penz. is pathogenic on leaves of *Prunus persica* Stokes. It could easily infect uninjured leaves of the host. The fungus did not develop setae under natural conditions, but did so on certain synthetic media, which established that the formation of setae was determined by the type of nutrition and environment. Similar conclusions were reached by Stevens and Hall (1909) for *Colletotrichum carica*, Kendrick and Walker (1948) for *Colletotrichum phomoides*, Ikata (1936) for *Gloeosporium kaki* and *Colletotrichum capsici* and Saccas (1959) for *Gloeosporium alborubrum* and *Colletotrichum heveae*. The present fungus was able to infect leaves of several other host species when cross inoculated. Thus it was not a specialized parasite.

The necessity of applying the fungicide just before or after infection clearly indicates that the application must be carefully timed. Applications at other intervals though kept down the infection but the damage was considerable. It appears desirable to spray the plants with Flit 406 at regular intervals.

Summary :

Colletotrichum gloeosporioides Penz was isolated from diseased spots on the leaves of *Prunus persica* Stokes and the symptoms of the disease have been described. Cross inoculations on *Carissa carandas*, *Artocarpus integrifolia*, *Bauhinia variegata*, *Citrus limettioides*, *Mangifera indica*, *Psidium guajava*, *Gossypium neglectum*, *Pothos scandens* and *Grewia asiatica* were successful. Dusting the leaves with Flit 406 decreased the intensity of infection and could control the disease only when it was applied within 48 hours before or after inoculation.

Acknowledgement :

Authors are thankful to Dr. K. S. Bilgrami, Assistant Professor, Department of Botany, University of Allahabad, for his help during the progress of the present investigation, and to Dr. R. S. Mathur, Plant Pathologist, U. P. Govt. for supplying some of the fungicides used in this investigation.

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THE EFFECT OF APPLICATION OF BORON AT VARIOUS LEVELS ON ANATOMICAL DISORDERS IN ROOTS OF *PHASEOLUS RADIATUS* (MOONG TYPE 1)

By

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[Received on November 14, 1961]

Not much has been reported on the response of anatomical structure of plants to the application of boron. Brenchely and Thornton (1925) studied the effect of the application of boron on the development, structure and functioning of the root nodules of *Vicia faba*. Webber (1935) reported that the formation of gum-pockets was the result of the disintegration of the elements of xylem caused as a result of the deficiency of boron. Jolviette and Walker (1943) reported the heterotrophy of cambium, degeneration and necrosis in the primary and secondary xylem, inter-cellular brown deposits, cell enlargement, and proliferation extending to mesophyll and spongy parenchyma of floral axis of sugar beet. Palser and Mc Ilrath (1956) reported that lack of boron as well as its excess caused the deformation of the vascular tissues in several plants.

In the present investigations the effect of boron at different levels of supply has been studied on the root anatomy of *Phaseolus radiatus* (Moong type 1).

Materials and Methods :

Phaseolus radiatus (Moong T 1) plants were raised in acid washed coarse sand, neutral to litmus, obtained from the bed of river Jamuna in clay pots coated twice with bituminous paint after the recommendations of Hewitt (1947). The nitrogen deficient nutrient solution of the following composition as recommended by Singh (1951) was used :

KH_2PO_4	0·5 gm
$MgSO_4$	0·2 gm
Tri-ca-PO_4	2·0 gm
$FeCl_3$	0·01 gm
K_2HPO_4	0·5 gm
NaCl	0·1 gm
$FePO_4$	0·5 gm
Distilled water	1,000 ml

To supply the essential micronutrient the solution B of Hoagland and Arnon (1940) with the following composition was added to each litre of the above macronutrient solution.

H_3BO_3	2·86 mg
$MnCl_2.4H_2O$	1·81 mg
$CuSO_4.5H_2O$	0·08 mg
$ZnSO_4.7H_2O$	0·22 mg
$H_2MoO_4H_2O$	0·09 mg

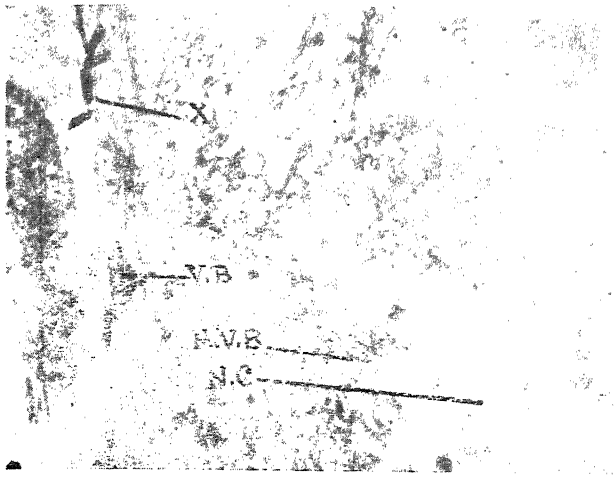

Plate 1. The effect of withholding boron from the culture medium on the anatomy of root at the age of 75 days.

X—Necrotic xylem area.
V B—Vascular Strand in L. S.
N.V.B—Nodular Vascular Bundle.
N.C—Nodular Cortex.

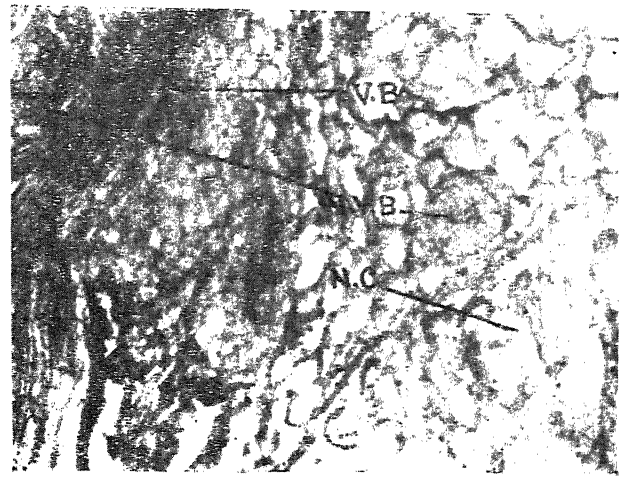

Plate 2. The effect of supplying boron at 0·5 ppm level on the anatomy of root at the age of 75 days.

V.B—Vascular Strand in L. S.
N.V.B—Nodular Vascular Bundle.
N.C.—Nodular Cortex.

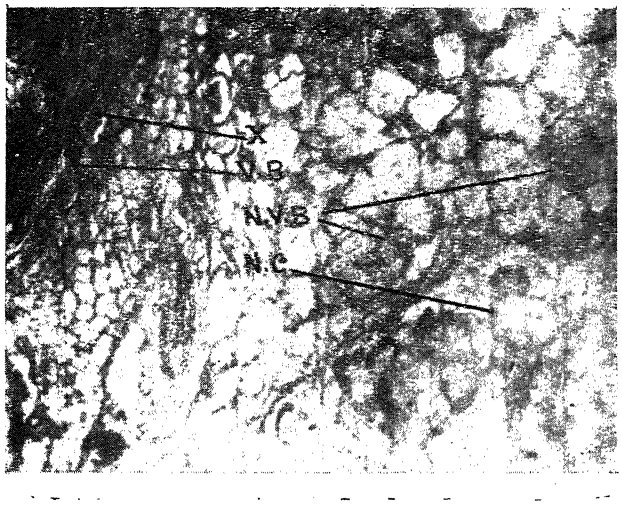

Plate 3. The effect of supplying boron at 1 00 ppm level on the anatomy of root at the age of 5 days.

X—Necrotic xylem area.
V P—Vasular Strand in L S.
N.V.B—Nodular Vascular Bundles.
N.C—Nodular Cortex.

No boron was supplied to the plants of deficient series (B-zero). The plants of the series B_1 and B_2 were given additional supply of boron as boric acid at the two levels, *viz.*, 0·5 ppm. and 1·00 ppm respectively for every 100 ml. of the nutrient solution applied to the cultures every 48 hrs. Distilled water was supplied on alternate days and this alternation of the nutrient solution with the supply of the distilled water continued throughout the life of the plants.

Twenty pots each having three plants constituted a series. The material for the anatomical study reported herein was taken at the age of 75 days and fixed in F. A. A. The roots with the attached root-nodules were dehydrated by passing the material through various grades of alcohol and xylol and finally embeded in pre-filtered paraffin wax. Only longitudinal sections of the root portions with attached root-nodules were cut. The sections, 8μ in thickness, were stained suitably to differentiate the various vascular elements for proper identification.

Observations :

The cells of the cortical region of the root were broken and the xylem elements were of the pitted form. Large gaps were formed as a result of the distortion of the smaller elements of the tissues of xylem. The cells of the phloem least affected in the radial plane, were broken due to stretching and straining (Plate 1). The nodules of the (B-zero) series of the plants had broken cortex, a smaller number of the nodular vascular bundles which had less vascular elements as compared to the nodules of the other two series were detected.

Contrary to the plants of the deficient series the plants of the B_1 series receiving 0·5 ppm of extra supply of boron had the intact vascular makeup. The cells of the cortex as well as the xylem (composed of scleriform elements) did not show any indication of breaking. The nodules of the B_1 series had a larger number of the nodular vascular bundles with well marked formation of the xylem as well as the elements of phloem (Plate 2).

The application of boron at the level of 1 ppm (B_2) caused the breaking up of the cortical cells (Plate 3). The phloem was ill formed and the full root structure could not be studied because of the well-marked disintegration of the cells in the various zones of root. The elements of the xylem, though well formed, were broken and of the scleriform type. The elements of the vasuclar bundles entering the nodular make up also showed disintegration at points.

Discussion :

The response of the vascular tissues of the root of *Phaseolus radiatus* (Moong type 1) to different levels of boron application as described herein served to corroborate the recent observations of Palser and McIlrath (1956).

Haas and Klotz (1933), studying the anatomy of citrus, observed increased cambial activity which gave rise to relatively undifferentiated secondary xylem with only occasional small, abnormally matured vessels followed by maturation of the cambial zone as parenchyma, or by abnormal radial elongation of the cells of the same accompanied by necrosis. The death of the tissues took place as a result thereof. Similar general effect of the deficiency had been described by Jolviette and Walker (1943) and Walker (1944) respectively on cabbage, by Van Schreven (1935) on tobacco and tomato, by Warington (1926) on *Vicia faba.*

The net effect of the deficiency of boron as well as its toxicity was the degeneration of the tissues which followed little differentiation of the cells and consisted of the heterotrophy, and ultimate death of the tissues. The retardation of the formation of vascular elements, as is evident in the present investigations, in the

B-zero series led ultimately to the reduced number of the Vascular bundles in the roots of *Phaseolus radiatus*. These findings are in close agreement with those of Brenchley and Thornton (1926). The effect of the deficiency was manifested in the formation of blackened patches as a result of the coalation of the patches formed due to the presence of the thick walled, often dark coloured, and sometimes crushed cells in the centre.

Summary and Conclusion :

A study of the anatomical disorders in the roots of *Phaseolus radiatus* (Moong type 1) grown in relatively controlled sand culture conditions with varying doses of boron supply was made at the age of 75 days.

The material was fixed in F. A. A., dehydrated, and embedded in filtered paraffin wax. The meterial was sectioned at a thickness of 8μ. Permanent slides were prepared and studied.

It was found that the deficiency as well as the excess of boron even at 1 ppm level produced a pronounced effect on the conducting tissue of th roots. There was a degeneration of the elements of xylem tissues in both toxic as well as the deficient series of boron of the plants of which only the root portion was studied. The other effects of the toxicity and deficiency of the microelement was the breaking of the cells of the cortical region.

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SPORE CONTENT OF AIR OVER PADDY FIELDS
II. CHANGES IN A FIELD NEAR VISAKHAPATNAM FROM NOVEMBER 3, 1959 TO JANUARY 9, 1960

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[Received on September 29, 1962]

In India in the Andhra University an aerobiological survey of the air over paddy fields was started recently using the automatic volumetric spore trap designed by Hirst (1952) for continuous air sampling. From the results of a study conducted in a field near Pentapadu village (3 miles to Tadepalligudem in the west Godavary district of the Andhra Pradesh) from September 21 to December 31, 1957, Sreeramulu and Seshavataram (1962) emphasized the need for undertaking a continuous survey extending over a period of about 2 to 3 years. With a view to observing the changes in the different components of the air-spora, continuous spore trapping was started in a paddy field near Visakhapatnam from November, 1959 and the results obtained in this study till the end of the first week of January, 1960 (the end of the main crop season in the area) are presented in this paper.

Methods :

The Hirst spore trap was installed in a 8-acre plot devoted to rice cultivation, with its orifice kept at a height of 1·75 metres above the ground level. The plots in the field were sown with the varieties MTU 10 and AKP 8. Adhesive slides for exposure in the trap were prepared using a 'Vaseline'-Wax mixture. The slides were mounted unstained in 'Solvar' and scanned at 2—hourly intervals. As the identification of the spores caught could be based only on the microscopic evidence, in possible cases only specific and generic counts were made and most of the other types are 'form groups'. The number counted on a traverse was converted into an estimated number per cubic metre of air taking the efficiency of the trap as 60% for all the spore types.

Results :

To show the day-to-day variations in the concentration of the different spore types, the estimated daily means for each of the eighteen spore types and the daily means of the 'total air-spora' are plotted in the different panels of Fig. 1. This method of plotting is chosen as it gives an idea of the relative frequencies of the different spore types at any time in the season. The changes in the weather conditions (from the data recorded on self-recording meteorological instruments located at the Visakhapatnam aerodrome) are also shown in the upper panels of Fig. 1. Some of the salient features observed for each type are presented below :

Cladosporium.—Spores belonging to this genus were present in the air throughout the trapping period in very high numbers forming the most important element of the air-spora. They showed a gradual increase till they reached their

seasonal peak in the middle of December. Their daily peaks recurred at 10.00 hr. and their concentrations even during the night time were considerably high. About 14,400/m^3. was the average concentration observed at their daily peak hour.

Basidiospores.—Spores of this composite group constituted the second biggest group in the total air-spora, although high numbers were caught only during the first half of November. They were present in very low concentrations during the day time and their daily maxima were observed at midnight with a mean daily peak concentration of about 7,500/m^3. of air.

Aspergilli type.—Spores of many common moulds like *Aspergillus* and *Penicillum* (usually caught in chains) were counted under this group. Some times they occurred in clumps, the number in a clump showing great variation. Spores of this composite group occurred in air in relatively high concentrations throughout and in the middle of November and in the beginning of January considerably high numbers were caught. Although they were caught at all times throughout the day, their daily peak (with an average of 3,000/m^3.) was generally found at 18.00 hr.

Fusarium.—Septate-fusiform spores showing the characteristic features of the macroconidia of *Fusarium* were counted under this category. Higher concentrations of this type were observed in the first half of November than at other times. Their daily maximum (of about 1,340/m^3.) recurred at 02.00 hr.

Unclassified group.—As one of the objects of this study was to record the total number of spores present in the air, all fungus spores caught on the slides, other than those which could be included under any of the 17 named groups, were counted under this category. This is a heterogeneous group and as such its composition changed considerably throughout the season.

Hyphal fragments.—Fragments of the vegetative hyphae, conidiophores, etc. were encountered on many slides. To get an idea of the total number of air-borne fungus parts, these were also counted. They occurred in the air in appreciable numbers on almost all days. Relatively high numbers were caught during the day time.

Bunts.—Spores of bunt fungi occurred in more or less uniform numbers in November, but in December, especially during the period when harvesting of the rice crop in the fields was in progress, comparatively high numbers were caught. The daily maximum for these spores recurred at 18.00 hr. with a mean of 250/m^3. of air.

Periconia.—There was very little fluctuation in the number of *Periconia* spores caught on different days in this period. Their daily maximum was found occurring at 18.00 hr. with a mean concentration of 200/m^3. of air

Trichoconis padwickii —Typical diurnal and seasonal periodicity was observed in the numbers of air-borne spores of this fungus. They were present in high numbers in the first half of November, showed a gradul decrease till the middle of December when they completely disappeared. Daily maxima (of about 85/m^3.) was observed at 10.00 hr.

Nigrospora.—Spores of this fungus with their daily peaks (of 100/m^3.) recurring at 08.00 hr. were caught in considerable numbers throughout this period.

Curvularia.—Comparatively high numbers of *Curvularia* spores were caught during November, and they showed a gradul decrease during December and January. They were caught in high numbers between 10.00, and 18.00 hr. (45/m^3.) on those days when they occurred in air.

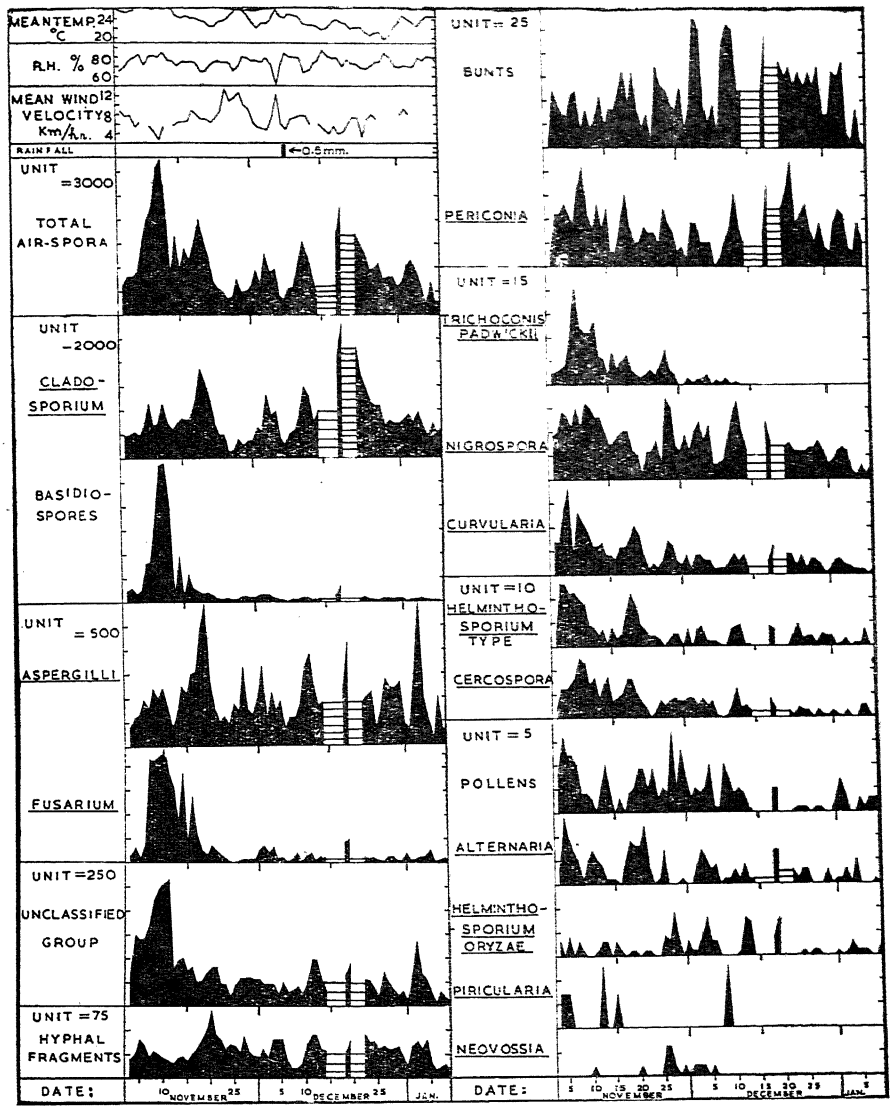

Fig 1. Changes in the daily mean concentrations of the different components of the air-spora, per cubic metre of air, with some meteorological data.

Helminthosporium type.—All spores belonging to *Helminthosporium* (except those that are included under *H. oryzae*) were counted under this group. Highest concentrations of this type were noticed in November ; there was a decrease in their numbers in December and in January very low numbers were recorded. They were caught at almost all times in the day but on most days peak concentrations (of 20/m^3.) were observed in the afternoon.

Cercospora.—These spores were caught on almost all days but relatively high numbers appeared only during November. They were present in the air throughout the day but their daily peak recurred (with an average of 45/m^3.) between 08·00 and 10·00 hr.

Pollens.—This is again a composite group in which all the pollen grains caught on the slides were included. Comparatively high numbers occurred in November when the late tillers of the rice crop and many of the weeds in the field were in flowering. An average concentration of 36/m^3. was observed at 10·00 hr., their daily peak hour.

Alternaria.—Spores of this type were caught on many days but comparatively high numbers appeared in November. In their diurnal periodicity they showed an afternoon peak with a mean concentration of about 16/m.^{3} of air.

Helminthosporium oryzae.— Conidia of this fungus were caught on some days only. Daily peak for this type occurred in the afternoon.

Piricularia.—Spores of this fungus were caught on few days in very low numbers.

Neovossia.—Spores of this fungus appeared continuously from November 25 to December 5, in very low numbers.

In order to indicate the main constituents of the total air-spora observed during this period in this locality, the highest daily mean concentrations and their average values for all the days, together with the percentage each type contributed to the total air-spora is given for each spore type in Table 1. The highest hourly concentration recorded for each type and the total air-spora, together with the percentage contribution at that particular hour are also included in Table 1, to indicate the relative importance of the different spore types at times when they were occurring in their maximum numbers. Records of the temperature and R.H. at the times at which highest numbers of the different spore types were encountered are also given.

Discussion :

By the time air-sampling was started, the rice crop in the field had already reached the 'milky-ripe' stage. The grains in the ears were filled up by the middle of November and early in December ripening was over and the crop was ready for harvest. Harvesting was started on December 5, and was completed by December 15. After cutting the crop, it was left flat in the field for drying and it was collected and removed from the field on December 17, 18 and 19, for staking. Except on December 8, (when there was a rainfall of 0·5 mm.–0·1 mm. at 15.00 hr. and 0·4 mm. at 19.00 hr.) the weather was dry throughout this period. The changes in the concentrations of many spore types observed in November and December, depended on the changes in the growth phases of the rice crop in the field.

TABLE 1

Relative contributions of the different spore types to the total air-spora from November 3, 1959 to January, 9 1960

Spore Category	Highest daily mean concentration		Mean for season	Percentage in total air-spora	Highest hourly concentration					Total air-spora at that hour	Percentage in total air-spora
	Date	No./m³. of air	No./m³.		Date	Time I.S.T.	Temp. °C.	R.H. %	No./m³. of air	No./m³.	
Cladosporium	19-12-59	11,464	3,474	54·00	19-12-59	14·00	29·2	40	41,968	49,163	85·26
Basidiospores	11-11-59	11,610	1,122	17·69	11·11-59	24·00	24·1	94	62,178	125,436	49·17
Aspergilli	3-1-60	2,996	1,016	15·72	3-1-60	12·00	28·1	43	26,746	29,531	90·56
Fusarium	10-11-59	1,234	197	3·07	11-11-59	24·00	24·1	94	4,042	126,436	3·18
Unclassified group	11-11-59	1,323	356	5·54	11-11-59	24·00	24·1	94	6,395	126,436	5·05
Hyphal Fragments	20-11-59	209	87	1·36	19-12-59	14·00	29·2	40	425	49,163	0·81
Bunts	4-12-59	145	55	0·86	5-12-59	18·00	24·4	58	430	7,324	5·87
Periconia	24-12-59	112	42	0·65	19-12-59	14·00	29·2	40	430	49,163	0·81
Trichoconis padwickii	8-11-59	65	8	0·13	8-11-59	12·00	29·6	46	340	16,226	2·09
Nigrospora	27-11-59	49	24	0·38	10-12-59	08·00	24·4	77	238	6,771	3·36
Curvularia	6-11-59	55	13	0·20	8-11-59	12·00	29·6	46	170	16,226	1·04
Helminthosporium type	4-11-59	26	6	0·10	4-11-59	12·00	30·0	46	85	2,542	3·34
Cercospora	8-11-59	25	7	0·11	8-11-59	12·00	29·6	46	102	16,226	0·69
Pollens	27-11-59	17	4	0·08	27-11-59	10·00	27·3	49	85	6,636	1·28
Alternaria	4-11-59	14	3	0·05	19-12-59	14·00	29·2	40	51	49,163	0·10
Helminthosporium oryzae	27-11-59	9	2	0·03	27-11-59	24·00	25·0	76	51	6,497	0·78
Piricularia	12-11-59	13	1	0·02	8-12-59	14·00	25·0	76	172	11,402	1·50
Neovossia	25-11-59	3	–	0·01	25-11-59	20·00	23·7	80	17	6,378	0·26

The results presented in this paper agree very well with those recorded from the air over a paddy field near Pentapadu by Sreeramulu and Seshavataram (1959, 1962) and are in fair agreement with those of Panzer, Tullis and Van Arsdel (1957) reported from a paddy field in North America. The diurnal and seasonal periodicities recorded here confirm the earlier observations from Pentapadu and agree well with the reports (Gregory, 196¹) from elsewhere. The general changes observed in the months of November and December in the two different years (1957 and 1959) at different places Pentapadu and Visakhapatnam) which agree very well with each other indicate that these are some of the main features of the air-spora of paddy fields during this part of the main crop season in the coastal districts of the Andhra Pradesh.

Summary :

Using a Hirst spore trap for continuous air-sampling, quantitative data on the diurnal and seasonal changes for 18 spore types along with their percentage contributions to the total air-spora of a paddy field near Visakhapatnam are presented for the period from November 3, 1959 to January 9, 196). From a comparision of these results with the changes observed in a paddy field at Pentapadu in 1957 (described in Part I of this series), it is concluded that the changes reported here indicate some of the main features of the air spora of paddy fields during this part of the main crop season in the coastal districts of the Andhra Pradesh.

Acknowledgements :

We are grateful to the India Council of Agricultural Research, New Delhi, for financal assistance and to the Director, Regional Meteorological Centre, Madras, for the supply of meteorological data recorded at the Visakhapatnam aerodrome. Our thanks are also due to the late Sri. G. Jagannadha Raju and his son Sri. G. Ramachandra Raju for permitting us to conduct this study in their field ; to Sri. M. B. V. Narasinga Rao and Prof. J. Venkateswarlu of this department for their interest.

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LEAF SPOT DISEASES OF SOME COMMON ORNAMENTAL PLANTS

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[Received on October 31, 1962]

Introduction :

Leaf spot diseases are actually expressions or symptoms of an abnormal or injurious phase incited by a living organism. This is a physiological disorder which continues till the pathogen finds the conditions of the host quite convenient for its metabolic activities. These diseases are sometimes responsible for enormous losses, as an untimely destruction of the foliage may not only reduce the photosynthetic area but may even kill the plant due to repeated defoliation. Leaf spot causing organisms victimize and strike down some of the most handsome trees which are often rendered unsightly. Plants exhibiting such symptoms have received comparatively little attention from the plant pathologist. In a majority of cases they have been left uncared and altogether no attempt has been made even to know the pathogens which deprive the plants of their natural grace and usual food supply. The ugly looks of a plant may not cause so much concern if its metabolic functions are normal and unhampered. A critical and scientific approach is needed to acquire full information about the organisms which attack one of the most physiologically active parts of the plant *i.e.*, the LEAF.

The importance of these diseases prompted the author to undertake systematic work from February 1957. The present paper deals with the symptoms of various leaf spot diseases, infection range of the pathogens and the viability of their conidia. Since the host plants belonged to various groups, their arrangement in alphabetical order was considered to be most appropriate.

Materials and Methods :

The diseased leaves of various plants were collected at frequent intervals of about a fortnight. The symptoms of the disease on different hosts were recorded. Slides from the infected portions were prepared for the study of the morphological characters of the pathogens and the various measurements of different structures were carefully recorded. The associated organisms were subsequently isolated by the usual method. Pathogenicity tests were conducted by random spraying of the spore suspension on the leaves of the respective hosts, whenever more than one organism was isolated from a particular leaf spot the pathogenicity of individual organisms was determined separately. Attempt was also made to study the host range. The details about it are given at various places in the text.

The viability of the spores at different stages was determined by separating the fruiting bodies (*viz.*, pycnidia, acervuli or perithecia) from the diseased leaves of the host, stored in the laboratory at room temperature at regular intervals of 15 days. The spore bearing bodies were gently crushed on a clean sterilized slide. A drop of sterilized distilled water was placed over the liberated spores and the slides were subsequently placed in moist glass chamber for 20 hours after which they were microscopically examined to study the spore germination. The length of time upto which they retained the capacity of germination was determined. In

those cases where Moniliales were responsible for the leaf spots the method was slightly modified and the spores were scraped after moistening the leaves and keeping them in moist chambers for 4-5 hours.

Records :

1. **Bauhinia purpurea** L.

Family—Leguminosae

Organism : *Phyllosticta bauhiniae* Cooke.

Da Costa and Mundkur (1948) recorded it earlier at Pusa and Bombay.

The disease was observed at Allahabad in February 1957. The infection usually started in the month of August or September. Irregular scattered spots were developed over the lamina. Within a week the lesions assumed cinnamon-brown colour. Subsequently minute, black, erumpent pycnidia were produced in the lesions (Plate 1, fig. 1). Occasionally adjoining infected regions coalesced with each other occupying large areas which were usually not limited by the veins. In some cases the spots became brittle and dropped out by February, leaving holes in the middle of the spots. Isolations invariably led to the appearance of *P. bauhiniae* in culture.

Morphological characters of the isolate : Hyphae hyaline, branched 3–3·9μ wide ; pycnidia ostiolate, black, mostly globose (110–138$\times$90–120μ wide) ; conidia hyaline and elliptical 7–7·8$\times$2–2·3μ.

Viability of the conidia—10 months.

Artificial inoculations were successful on 80% leaves.

Cross inoculations were successful on the leaves of *Callistemon indica* and *Dracaena terminalis*. They failed on other host of *Phyllosticta* species included in these studies.

Localities—Botanical Gardens, Allahabad University ; Park Road, George Town, Shankargarh and Jhunsi .

2. **Callistemon indica** Roxb.

Family—Myrtaceae.

Organism—*Phyllosticta flavidula* Sacc.

Nearly all the plants of *Callistemon indica* in the University Botanical Gardens as well as in other private gardens suffered from a serious leaf spot disease in 1957. Infection usually started in August—September. The tips of the healthy leaves first turned to light olive colour. In some cases the infection reached upto the leaf base and killed the entire leaf. After about 15—20 days of infection black pycnidia appeared on the upper surface of the infected foliage. The colour of the older diseased regions ultimately changed to deep grayish olive. By March the diseased portions from the tips gradually started separating from the healthy tissues. Isolations consistently yielded *P. flavidula* in culture.

Morphological characters of the isolate : Hyphae cream coloured, 2·3—2·9μ wide ; pycnidia protruded from the host, generally black and globose, about 110μ in diameter ; conidia ovoid, very small, honey coloured, 2·5–3$\times$1–1·3μ.

Viability of the conidia—11½ months.

Artificial inoculation gave positive results on 85% leaves.

The organism failed to infect other hosts, susceptible to species of *Phyllosticta* included in these studies.

This is the first record of *P. flavidula* in India.

Localities—Botanical Gardens, Allahabad University ; Alfred Park ; Residential colonies of Fort Road and C. Y. Chintamani Road.

3. **Canna indica** L.

Family—Cannaceae.

Organism : *Fusarium sambucinum* Fuckel.

In January 1959 the leaves of *Canna indica* exhibited typical symptoms of browning from the tips and occasionally from the margins. In the former case the infection gradually proceeded towards the base. Sometimes the upper diseased portion of the leaf blade developed curling and ultimately got dissociated from the healthy portion. Infection from the margins was restricted to about 30% cases and the infection proceeded towards the centre. The curling was more pronounced than in the former type of infection. Isolation and pathogenicity experiments established that *Fusarium sambucinum* was responsible for this disease.

Morphological characters of the fungus : Hyphae richly branched, closely septate, hyaline or flesh coloured, about 4μ wide ; chlamydospores globose, generally in chains 5–6μ in diameter ; conidia borne at the tips of the conidiophores ; macroconidia slightly curved and pointed at both the ends, usually three septate but some of them were four or five septate, very rarely few conidia were more than si celled :

$$\text{Size} \begin{cases} \text{3 septate} : 18\text{–}39 \times 3{\cdot}5\text{–}6\mu \\ \text{4 septate} : 21\text{–}46 \times 3{\cdot}9\text{–}6\mu \\ \text{5 septate} : 25\text{–}57 \times 4{\cdot}0\text{–}6{\cdot}3\mu \end{cases}$$

Microconidia small, cylindrical, hyaline 3–5 × 1·5–2·0μ in size.

Viability of the conidia—6½ months.

Artificial inoculations resulted in infection to 70% leaves.

The pathogen could easily infect the leaves of *Sansevieria macrophylla*, *S. cylindrica*, *Quisqualis indica* and *Fothos scandens*. It failed to infect the leaves of *Carica papaya* and *Cajanus cajan*.

So far *F. sambucinum* was not reported to be associated with the leaf spots of *Canna indica*.

Localities—M. L. Nehru Park and Botanical Gardens of C. M. P. Degree College, Allahabad.

4. **Cycas revoluta** Thunb.

Family—Cycadaceae.

Organisms : 1. *Phyllosticta cycadina* Pass.
2. *Ascochyta cycadina* Scalia.
3. *Teichospora indica* Tandon et Bilgrami.

The symptoms of the disease caused by infection of *P. cycadina* have been described earlier by Tandon and Bilgrami (1954).

Chibber recorded it in Bombay Presidency in 1916. Bilgrami (1956) established the pathogenicity of the organism on the leaflets of *Cycas revoluta* and described other details. (Plate I, fig. 2).

In January, 1957, *Ascochyta cycadina* was also isolated from the diseased leaves of *Cycas revoluta*, exhibiting symptoms which were almost similar to those produced by *P. cycadina*.

Morphological characters of *Ascochyta cycadina* : Hyphae 2·6–3·2μ wide ; pycnidia epiphyllous, dark brown, sparse, flattened or slightly globose, partially embedded into the host, upto 300μ in diameter, ostiolate, circular, slightly protruded ; conidia oblong, rounded at sides, light olive, bicelled with no distinct constriction at the point of septation.

Viability of the conidia—9½ months.

Artificial inoculations resulted in infection to 55% leaves.

Cross inoculations gave positive results on the leaflets of *Cycas rumphii*. They failed on the leaves of *Phaseolus mungo, Pisum sativum, Santalum album* and *Artocarpus heterophyllus*.

Localities—Botanical Gardens, Allahabad University and near District Courts.

Teichospora indica was also recovered from similar lesions in January, 1957.

Morphological characters of *Teichospora indica* : Perithecia separate, black, globose, slightly immersed in the palisade of the host, 108·8–216·7 × 95·2–186·6μ ; asci long, hyaline, cylindrical 64–65 × 15–17μ ; eight ascospores in each ascus. Ascospores dark brown muriform with three transverse septa and one longitudinal septum 14–15 × 5–6μ (Plate I, fig. 3).

Viability of the ascospores—5½ months.

Pathogenicity tests were unsuccessful.

Locality—Botanical Gardens, University of Allahabad.

Tandon and Bilgrami (1960) established that *T. indica* was the perfect stage of *P. cycadina* and they were thus related to each other. (Plate I, figs. 4 and 5).

5. **Cycas rumphii** Miq.

Family—Cycadaceae.

Organisms : (1) *Ascochyta cycadina* Scalia

Ascochyta cycadina was isolated from the leaflets of *C. rumphii* in January, 1958. The morphology of the isolate was similar to the one infecting the leaflets of *C. revoluta*. External symptoms on the host were also identical to those caused by *Phyllosticta cycadina* on *Cycas revoluta*.

Viability of the conidia—9 months.

Artificial inoculation caused infection to 80% leaves.

A. cycadina isolated from the leaflets of *Cycas rumphii*, could easily infect the leaflets of *Cycas revoluta*. This isolate also could not infect any of the hosts which were not attacked by the isolate from *C. revoluta*.

Locality—Botanical Gardens, University of Allahabad.

(2) *Curvularia verruculosa* Tandon et Bilgrami.

Morphological characters of the isolate : Conidiophores light brown, simple, unbranched, straight or bent, lateral or terminal highly geniculate near the tip, length variable, 3–4·2μ wide ; conidia straight, fusiform or curved, brown, three septate with broad septa, no constriction at the point of septation, third cell from the base slighty bigger and sometimes curved, basal cell light brown and shows the point of attachment, wall of the conidia rough and slightly verruculose, 24·18 × 11·96μ (range 20·8–26·0 × 10·6–12·8μ).

Viability of the conidia—7½ months.

Artificial inoculations caused infection to 85% leaves.

Typha latifolia and *Anona squamosa* were susceptible to *Curvularia verruculosa* while the cross inoculations failed on the leaves of *Pennisetum typhoideum* and *Sorghum vulgare*.

Localities—Botanical Gardens, University of Allahabad.

6. **Dahlia rosae** Desf.

Family—Compsitae.

Organism : *Alternaria tenuis* Nees.

The disease was first noticed in March 1959. It was characterized by chestnut brown necrotic areas which were usually marginal and they extended to the entire width of the leaf blade. Severe infection deprived the leaf of entire photosynthetic area. The diseased areas were often zonate. The older leaves were more susceptible and were infected much earlier. *Alternaria tenuis* Nees, was found to be invariably associated with the diseased areas.

Morphological character of the fungus : Hyphae dark brown, about 5μ wide ; conidiophores short, septate, branched or unbranched, of variable length, 5-6μ wide ; conidia muriform with 3-5 transverse septa and 1-2 longitudinal septa, generally in chains (Plate 1, fig. 6), outer wall very rough and warted, brownish-black, 28–32 × 12–16μ.

Viability of conidia—8 months.

Artificial inoculation resulted in infection to 65% leaves.

Leaves of *Dahlia variabilis* and *Lactuca sativa* were susceptible to this isolate while cross inoculations on the leaves of *Brassica campestris*, *Datura stramonium* and *Nicotiana tabacum* were unsuccessful.

A. tenuis has been recorded for the first time on this host.

Localities—M. L. Nehru Park and Hamilton Road.

7. **Dahlia variabilis** Desf.

Family—Compositae.

Organism : *Alternaria tenuis* Nees.

The same isolate of *Alternaria tenuis* was also responsible for serious leaf spotting of this host also. Symptoms, degree of succeptibility and viability of the conidia were similar to those on *D. rosae*.

Earlier records do not list this fungus in association with the leafspot disease of *Dahlia variabilis*.

Localities—M. L. Nehru Park ; Botanical Gardens, Allahabad University and Hamilton Road.

8. **Dracaena terminalis** Van.

Family—Liliaceae

Organisms : 1. *Phyllosticta dracaenae* Griff and Maubl.

2. *Dictyoarthrinium sacchari* (Stevenson) Damon.

It was observed that most of the older foliage of *Dracaena terminalis* growing in the Botanical Gardens of Allahabad University had changed to walnut brown colour in September 1957. Infection usually started from the tip, occasionally it

was marginal or scattered also. By October, black erumpent pycnidia of *P. dracaenae* had abundantly developed over the diseased regions (Plate II, fig. 1). In general the diseased part remained attached to the leaf but occasionally a small part of the tip started separating by the end of February.

Sydow and Mitter (1935) had earlier reported it from Allahabad but pathological or nutritional studies were not conducted by them.

Morphological characters of the fungus : Hyphae light brown, 2·3–3·0μ wide ; pycnidia dark brown or black, variable in size 50–72 × 85–105μ, ostiolate ; conidia small and hyaline 2·5–3·2μ × 1·6μ.

Viability of the conidia—11 months.

Artificial inoculations caused infection to 70% leaves.

Cross inoculations were successful on the leaves of *Pandanus* sp. but they failed on other hosts of *Phyllosticta* included in the present investigation.

Localities—Botanical Gardens, University of Allahabad ; Park Road, George Town and Minto Park

In January, 1958, *Dictyoarthrinium sacchari* was isolated from the diseased leaves which exhibited similar symptoms like those produced by *Phyllostict dracaenae*. There was no visual difference in the spots developed by the two organisms.

Morphological characters of *D. sacchari* : Hyphae dark-slate in colour, 3·5–4·6μ wide ; conidiophores generally short and broad, 3·9–5·2μ long, closely septate, septa dark and wide ; lateral or terminal ; conidia dark brown, one to four celled, having the following average measurements : single celled conidia (6 × 5·5μ) ; tetralocular conidia (12 × 8·5μ). Four cells of a tetralocular conidia were arranged in a cross like manner, wall of the conidia rough and reticulate. The reticulate nature of the conidial wall was very distinct in young spores (Plate II, figs. 2 and 3).

Viability of the conidia—6½ months.

Artificial inoculations caused infection to 45% leaves.

Cross inoculations were unsuccessful on the leaves of *Musa paradisiaca* and *Heliconia rubra*.

D. sacchari is recorded for the first time on this host.

Localities—Botanical Gardens, University of Allahabad ; Park Road, George Town and Minto Park.

9. **Eucalyptus globulus** Labill.

Family—Myrtaceae.

Organism : *Pestalotiopsis funerea* (Desm) Steyaert.

Earlier Mundkur and Keshwalla (1942) reported this organism from Dehradun, Coonoor and Nilgiri hills.

Olive-gray scattered lesions were observed on the leaves of *E. globulus* in September, 1957. Dark brown acervuli were perceptible on the upper surface after a fortnight. Isolations from these areas invariably yielded richly fruiting cultures of *Pestalotiopsis funerea*.

Morphological characters of the fungus : Conidia five celled, oblong, slightly constricted at the septum, three middle cells blackish brown, two surrounding cells

hyaline with a little beaked apex, 20–31 × 6–9μ, usually furnished with two setulae on the apical side, setulae hyaline, slightly recurved 13–17μ long.

Viability of the conidia—9½ months.

Artificial inoculations caused infection to 60% leaves.

The organism was capable of infecting the leaves of *Eugenia jambolana*, *Eriobotrya japonica*, *Mangifera indica*, *Psidium guajava* and *Eucalyptus robusta*. Cross inoculations gave negative results on the leaves of *Lawsonia alba* and *Rosa canina*.

Localities—Liddle Road and Ewing Christian College.

10. **Ficus krishnae** Biswas.

Family—Moraceae.

Organism : *Nigrospora sphaerica* (Sacc.) Mason.

The entire foliage of *Ficus krishnae* in the University Botanical Gardens was almost unsparingly infected in September, 1958. The disease was usually initiated from the leaf base or the margins. In early stages the healthy tissues lost chlorophyll and assumed clay colour, but ultimately they changed to sepia. Generally the lesions from the two sides of the midrib did not coalesce (Plate II, fig. 4). The diseased areas were brittle. They first developed some cracks and ultimately they got detached. Isolations revealed consistent association of *Nigrospora sphaerica* with the infected tissues.

Morphological characters of the fungus : Hyphae about 4·0μ wide, light brown ; conidiophores lateral or terminal, slightly darker in colour, sometimes inflated to form a vesicle which bears a black, opaque, spherical conidia, 22–25μ in diameter (Plate II, fig. 5).

Viability of the conidia—8 months.

Artificial inoculation caused infection to 80% leaves.

Cross inoculations were successful on the leaves of *Elettaria cardamomum* and *Madhuca latifolia*. They failed on *Ficus religiosa* and *F. glomerata*.

The organism was not reported earlier on this host.

Locality—Botanical Gardens, University of Allahabad.

11. **Grevillea robusta** A. Cunn.

Family—Proteaceae.

Organism : 1. *Botryodiplodia theobromae* Pat.

The pathogen was isolated from silvery-gray leaf spots which appeared on this host in December, 1960. Isolations from the diseased portions resulted in *Botryodiplodia theobromae*. The fructifications of the fungus were more common on the upper than on the lower surface. The infection was always from the tips. The healthy and diseased portions were often separated by chlorotic bands. Crumpling and ultimate detachment of the diseased region was completed in majority of leaves by the end of February.

Morphological characters of the fungus : Hyphae dark-brown about 3·8μ wide ; stroma black, erumpent of variable size, with numerous locules, globose or pear shaped ; conidiophores short and erect about 7μ in length ; conidia single

celled, hyaline when young, dark brown and bicelled at maturity, 20–30×11–15μ (Plate II, fig. 6).

Viability of the conidia—11 months.

Artificial inoculations resulted in infection to 75% leaves.

The organism easily caused infection on the leaves of *Smilax simplex*, *Sansevieria macrophylla* and *S. cylindrica*. They gave negative results on *Dracaena terminalis*, *Ficus glomerata* and *F. religiosa*.

This is the first record regarding the association of *B. theobromae* with the leaf spots of *Grevillea robusta*.

Culture is deposited at C. M. I., Kew, and Botany Department, University of Allahabad (India).

Localities—Botanical Gardens, University of Allahabad ; M. L. Nehru Park.

12. **Heliconia rubra** L.

Family—Musaceae.

Organism : *Phyllosticta dardanoi* Baitista.

Leaf spot disease of *H. rubra* was first observed at M. L. Nehru Park, Allahabad in June, 1958. Healthy leaves of the host had developed clay coloured lesions. Black pycnidia of the pathogen were distinctly visible on the upper surface of the leaves. During July—August, the lesions increased in area and sometimes adjoining spots coalesced with each other. By January the detachment of severely infected regions started from the centre of the lesion. The peripheral infected zone, sometimes remained attached throughout the year. Isolations from the diseased parts gave *Phyllosticta dardanoi*.

Morphological characters of the pathogen : Hyphae richly branched, light creamish, about 2·0μ wide ; pycnidia ostiolate, light brown, small 28×25·2–78×67·6μ ; pycnospores hyaline, ellipsoidal 2–3·5×1–1.8μ.

Viability of the conidia—10½ months.

Artificial inoculations caused infection to 55% leaves.

Bauhinia purpurea was susceptible to this pathogen while all other hosts of *Phyllosticta* species were resistant to this species.

This is the first record of this organism in India.

Culture is deposited in C. M. I., Kew, and Botany Department, University of Allahabad (India).

Localities—M. L. Nehru Park, George Town, Lalgopalganj.

13. **Kigelia pinnata** D. C.

Family—Bignoniaceae.

Organism : *Phyllosticta kigeliae* Died.

Trees of *Kigelia pinnata* suffered with a serious leaf spot disease in November, 1957. At the initiation of infection the healthy leaves manifested yellowing of the margins. By December, the diseased areas enlarged considerably and changed to dark olive lesions (2–3·5 cm. in diameter). At this stage black erumpent pycnidia were distinctly visible on the upper surface of the leaves. The spread of the

lesions were usually restricted on the sides of the midrib only. The dead tissues were ultimately detached and thus the regular shape of the leaf was lost. Morphological expressions of the isolate showed that *P. kigeliae* was the causal organism.

Morphological characters of the fungus: Hyphae hyaline, 1·5–2·3μ wide, pycnidia dark brown, globose, ostiolate, usually clustered, 85–96×61–125 ; conidia ; hyaline, obtuse on both the sides 9·1–13·3×4–6·2μ.

Viability of the conidia—12 months.

Artificial inoculations caused infection to 80% leaves.

The isolate failed to infect other hosts of *Phyllosticta* included here.

There is no previous record of this organism from India.

Localities—Botanical Gardens, Univerity of Allahabad and Allahabad Agricultural Institute, Naini.

14. **Monstera deliciosa** Liehm.

Family—Araceae.

Organism: *Acrospeira fluctuata* Tandon et Bilgrami.

Plants of *Monstera deliciosa*, growing in the Botanical Gardens, University of Allahabad, as well as in M. L. Nehru Park, manifested large buffy-brown lesions in eptember, 1960. The infection usually started from the margins. Sometimes several discrete lesions coalesced and occupied large areas. Isolations invariably gave a species of *Acrospeira*. Due to differences in its morphology from all the existing species this fungus has been decribed as a new species and the details are given by Tandon and Bilgrami (1961).

Morphological characters of the isolate: Hyphae generally hyaline 3–3·6μ wide, average distance between the two septa about 20 ; few yellowish hyphae 6·5–7·0μ wide with close septation occasionally develeped ; conidiophore terminal as well as lateral, bright light brown in colour, 6·5–8·0μ wide, flattened terminally, often with a width upto 15 , bears dark brown conidia of very variable shape and size, may be 2 to 10 celled, with straight or oblique septa. The average size of the different types of conidia is detailed below (Plate III, figs. 1 and 2).

2 celled (12×7·8μ) ; 3 celled (15·4×13·0μ) ; 4 celled (13×12·6μ) ; 6 celled (25·6×12μ) ; 8 celled (28×4·3μ) ; 10 celled (33·5×15·0μ).

Viability of the conidia—6½ months.

Artificial inoculation caused infection to 93% leaves.

Cross inoculations were tried on a number of hosts including the leaves of *Dahlia variabilis*, *D. rosae*, *Lactuca sativa* and *Smilex macrophylla* but they were alll unsuccessful.

Localities—Botanical Gardens, University of Allahabad and M. L. Nehru Park.

15. **Nerium odorum** Soland.

Family—Apocynaceae.

Organism: *Phyllosticta glaucispora* Delacroix.

It was observed in August, 1959, that the leaves of *Nerium odorum* growing in the M. L. Nehru Park area had started turning dawn gray from the tip portion.

The infection gradually proceeded further towards the base and by the end of October it damaged a large part of the leaf and assumed a dark-plumbeous colour. Black pycnidia were distributed on the upper surface only. Diseased part was clearly separated from the healthy region by a prominent blackish-gray band. By February or March the severely infected portions ultimately detached from the healthy parts. The causal organism was identified as *P. glaucispora*.

Morphological characters of the fungus : Hyphae hyaline, about 2–3μ wide ; pycnidia dark brown, measuring 36–110×28–94μ ; conidia hyaline, cylindrical 2·3–3·0μ×1·3μ.

Viability of the conidia—13 months.

Artificial inoculations caused infection to 85% leaves.

Cross inoculations gave positive results on *Nerium oleander* only while other hosts of *Phyllosticta* were resistant to this species.

This fungus is reported for the first time from India.

Localities—Hamilton Road ; Fort Road ; Madhwapur and Pratapgarh.

16. **Nyctanthes arbor-tristis** L.

Family—Oleaceae.

Organism : *Sphaeropsis nyctanthis* Bilgrami.

The leaves of *Nyctanthes arbor-tristis* were found to be almost unsparingly spotted at Allahabad during September, 1959. In the early stages, the infection generally started from the tips when the leaves developed bright to pale yellow spots which gradually extended towards the leaf base. With the expansion of the lesions the necrotic tissues became light brown. Sometimes scattered brown spots surrounded by light yellow margins were also formed. In later stages, several discrete lesions occasionally became confluent and developed irregular spots. Under humid conditions the spots developed rapidly and the necrotic areas extended upto 2·5 cm. in diameter. Severe infection resulted in consider able defoliation. Fructification was usually abundant in central portion of the infection. Pycnidia were black, erumpent, partially embedded inside the host tissue. Isolations from the diseased regions showed that a species of *Sphaeropsis* was consistently associated with the diseased spots.

The detailed morphology of the organism did not agree with any of the existing species of *Sphaeropsis*. The fungus is peculiar for having a very thick walled pycnidium. A report on this culture from the Director of the Commonwealth Mycological Institute, Kew, showed that it could not be assigned to any of the known species. Mr. Sutton of that Institute mentioned that there was no record of any such fungus on this host. Due to the apparent differences in the habitat as well as in the measurement of the various structures it was decided to create a new species for accommodating this organism which has been named as *S. nyctanthis* sp. nov.

Morphological characters of the isolate : Hyphae 2·6–3·2μ wide, light brown richly branched. closely septate ; pycnidia black mostly spherical or slightly oblong (Plate III, fig. 3), immersed in the host tissue, variable in size 165×188·6–418·6 ×440μ conidiophores small 3×1·7μ ; conidia spherical (10·4μ in diameter) or oval

11·7–13·0×7·8–9·1μ, mostly black very few opaque brown (Plate III, fig. 4). Highly parasitic on the leaves of *Nyctanthes arbor-tristis.*

Culture is deposited in C. M. I., Kew and Botany Department, University of Allahabad (India).

Viability of the conidia—11½ months.

Artificial inoculations resulted in infection to 80% leaves.

Cross inoculations were made on the leaves of *Musa paradisiaca*, *M. sapientum*, *Cycas rumphii*, *C. revoluta* and *Pyrus malus* but they were all unsuccessful.

Locality—Muir Central College campus, University of Allahabad and Pratapgarh.

17. **Pandanus tectorius** Soland.

Family--Pandanaceae.

Organism : *Phyllosticta pandanicola* Young.

The plants of *P. tectorius* which were cultivated in most of the private gardens of the city showed grayish-white to light brown spots in March 1957. The infection generally started from the tips (Plate III, fig. 5). Some of the light brown spots were surrounded by slightly darker margins ; pycnidia were generally located in regular lines along the veins.

Morphological characters of the isolate : Pycnidia spherical to ovate ; 80–100×45–62μ, dark brown ostiolate ; conidia hyaline, elliptical, slightly pointed at the ends, 9–14×2·5–3·2μ. Under cultural conditions the organism sporulated abundantly on potato-dextrose agar and developed extensively branched, light brown mycelium with a width varying from 2·6–3·9μ.

Patel *et al.* (1949) had earlier reported this fungus from Bombay Presidency.

Viability of the conidia—10½ months.

Artificial inoculation caused infection to 85% leaves.

Cross inoculations on other hosts of *Phyllosticta* were unsuccessful.

Localities—Botanical Gardens, University of Allahabad ; C. Y. Chintamani Road ; Minto Park and M. C. College Gardens.

18. **Pithecolobium dulce** Benth.

Family—Leguminosae.

Organism : *Colletotrichum dematium* (Pers Ex Fr.) Grove.

Plants of *P. dulce* are used as common hedge and they serve as a good barrier for protecting the gardens. In September 1958, the leaves of this plant manifested yellow-ocher spots which were separated from the healthy areas by a cinnamon-drab zone. The infection was usually from the tips or from the margins (Plate III, fig. 6) but it could also be scattered anywhere on the leaf. The severity of the disease increased by the middle of November when smaller lesions coalesced to form bigger necrotic areas, sometimes extending across the midrib. Black fruiting bodies of the fungus were also prominently visible on the upper surface of the infected regions. The diseased portions ultimately became fragile and dissociated, producing 'shot holes' in the healthy leaves. Pathogenicity tests showed that *Colletotrichum dematium* was the causal organism.

Morphological characters of the isolate : Acervuli erumpent, round or oblong-light brown, often confluent. upto 315μ in diameter ; setae arise all over the acervuli, cylindrical, rigid, straight (Plate IV, fig. 1), sometimes slightly bent, septate, may be upto 350μ long and 8–12μ wide ; conidia borne at the apex of cylindrical conidiophores, straight, slightly curved or even fusoid 18–25 × 3·6–4·2μ.

Viability of the conidia—9½ months.

Artificial inoculations caused infection to 70% leaves.

Cross inoculations gave positive results on the leaves of *Dracaena terminalis* and *Carissa carandas*. They failed on the leaves of *Pothos scandens*, *Quisqualis indica* and *Capsicum annum*.

Localities—Botancial Gardens, University of Allahabad ; Liddle Road and Thornhill Road.

19. **Pothos scandens** L.

Family–Araceae.

Organism : *Colletotrichum capsici* (Syd.) Butl. et Bisb.

Leaves of *P. scandens* exhibited light brown circular spots in March 1957. The size of the spots increased with age, but the midrib was never infected and whenever the infection reached that area the spread was parallel to the vein. The shape of the spots was thus irregular near the veins. The colour gradually changed to dark brown and ultimately the acervuli of the fungus appeared on the upper surface of the diseased portions after 2–3 months of infection. The fruiting bodies were more concentrated towards the peripheral region. In the ultimate phase the affected areas dried up and collapsed leaving irregular holes in the centre. During moist weather the infected areas do not dry up but they get rotten. Isolations consistently yielded *C. capsici* having the following morphological character.

Morphological characters of the isolate : Conidia 28–33 × 3·0–3·6 μ hyaline ; acervuli 225–274 in diameter, carbonaceous ; setae 68–90μ long.

Srivastava (1953) reported a new species of *Colletotrichum* viz., *C. cylindricum* on this host from Poona. This species was not recorded at Allahabad or in its vicinity.

Viability of the conidia—11 months.

Artificial inoculations caused infection to 72% leaves.

Cross inoculations were successful on the leaves of *Quisqualis indica* and *Carissa carandas*, while they failed on the leaves of *Calotropis gigantea*, *Dracaena terminalis* and *Abelmoschus esculentus*.

Tandon and Agnihotri (1961) carried out physiological studies on on this isolate.

Localities—Botanical Gardens, University of Allahabad and Swarajya Bhawan.

20. **Quisqualis indica** L.

Family—Combretaceae.

Organism : *Colletotrichum capsici* (Syd.) Butl. et Bisb.

The leaves of *Quisqualis indica* manifested tawnyolive circular spots in November, 1959. The lesions gradually enlarged in size but were delimited by the midrib. Within 15–20 days of infection numerous sepia coloured acervuli appeared in the infected regions. The sporulation was profuse in the centre of the diseased regions. The lesions became very brittle by early January and finally they fell off,

leaving a peripheral infected zone which propagated the disease further. The infection was also common on young branches. Isolations from the diseased lesions gave *C. capsici* which sporulated profusely in culture.

Morphological characters of the fungus—Hyphae cream coloured 3·6–4·2μ wide ; conidia hyaline 19–24 × 3·5–5μ ; setae light brown, pointed at the tips 260–309μ long, 4·6–8μ broad. This isolate differs from the type specimen in having longer setae (Plate IV, fig. 2).

Viability of the conidia —9½ months.

Artificial inoculations caused infection to 65% leaves.

Cross inoculations were successful on *Pothos scandens*, *Dracaena terminalis* and *Carissa carandas*. They failed to infect the leaves of *Pithecolobium dulce*, *Ricinus communis* and *Abelmoschus esculentus*.

This is the first record of *Colletotrichum capsici* on the leaves of *Quisqualis indica*.

The culture and herbarium specimen are deposited in C. M. I., Kew, and Botany Department, University of Allahabad (India).

Locality–New Katra.

21. **Rosa canina** L.

Family—Rosaceae.

Organisms : 1. *Pestalotiopsis lespedezae* (Syd.) Bilgrami Comb. nov.
2. *Chaetomium funicola* Cooke.

The plants of *R. canina* growing in the Botanical Gardens of University of Allahabad exhibited olive-brown scattered spots in December, 1958. These spots were usually vein limited. Older lesions got detached from the healthy portion by the end of February and due to this irregular holes were developed on the leaves and they disfigured the host.

Morphological characters of the fungus : Hyphae hyaline, about 3 μ wide ; conidia light olive in colour, generally straight, 19–20·6μ × 5·6–7·2μ, apical hyaline cell usually with two setulae. In morphological and cultural characters, this species resembles *Pestalotia lespedezae* Syd. The culture was sent to C. M. I., Kew, Mr. Sutton examined and wrote that "conidia are very slightly thinner than *Pestalotia lespedezae* Syd., otherwise identical". The species is, therefore, disposed as *Pestalotiopsis lespedezae* (Syd.) Bilgrami Comb. nov.

Viability of the conidia—10 months.

Artificial inoculations caused infection to 50% leaves.

Cross inoculations with *Pestalotiopsis lespedezae* were tried on the leaves of *Eriobotrya japonica*, *Nephelium litchi*, *Mangifera indica*, *Psidium guajava*, *Eugenia jambolana* and *Eucalyptus globulus* but they were all unsuccessful.

Culture is deposited in C. M. I., Kew, and Botany Department, University of Allahabad (India).

Chaetomium funicola was also isolated from few infected leaves of the host which showed identical symptoms.

Morphological characters of the fungus : Perithecia dark brown, 108-156μ covered with hairs considerably elongated, upto 350μ long, may be dichotomously branched, sometimes incrusted (Plate IV, fig. 3) ; spores broadly obvate 4·5–6 × 4·2μ.

Viability of the ascospores—6½ months.

Pathogenicity tests failed.

Chaetomium funicola was inoculated on the leaves of *Psidium guajava*, *Eriobotrya japonica*, *Prunus persica* and *Potentilla* sp. but none of them were infected.

This is the first record of *Chaetomium funicola* on this host.

Culture is deposited in C. M. I., Kew, and Botany Department, University of Allahabad (India).

Locality–Botanical Gardens, University of Allahabad.

22. **Sansevieria cylindrica** Thumb.

Family—Liliaceae.

Organism : *Phyllosticta cycadina*, Pass.

The centric leaves of *S. cylindrica*, growing in various private gardens at Allahabad and Pratapgarh manifested honey yellow lesion in July, 1960. The spots were circular or oval measuring 0·5–1·2 cm. in diameter. Within next few months, the spots slightly increased in their dimensions. Pycnidia of the fungus were clearly visible over the diseased areas. In severely diseased parts the fungus penetrated deep into the tissues but it failed to pass from one end to the other. *Phyllosticta cycadina*, which was responsible for the leaf spot diseases of *Cycas revoluta* and *Sansevieria macrophylla* in all these gardens was isolated from the diseased areas.

Viability of the conidia—14½ months.

Artificial inoculations resulted in infection to 80% leaves.

Cross inoculations gave positive results on the leaves of *Sansevieria macrophylla* and *Cycas revoluta*. They failed on other hosts of *Phyllosticta* included here.

This fungus is recorded for the first time on the leaves of *S. cylindrica*.

Localities—Botanical Gardens, University of Allahabad ; Tagore Town and Kunda.

23. **Sansevieria macrophylla** Thumb.

Family—Liliaceae.

Organism : 1. *Phyllosticta cycadina* Pass.
2. *Diplodia sansevieriae* Syd.
3. *Fusarium semitectum* Berk et Rav.

The leaves of *S. macrophylla* had developed semi-circular spots of light buff colour in May, 1959. With age the infection pressed deep into the tissues and the diseased areas began to dry up. They subsequently assumed olive gray colour with simultaneous development of the fruiting bodies on the upper surface (Plate IV, fig. 4). Sometimes the infection was from the margins also. Tandon and Bilgrami (1960) reported that *Phyllosticta cycadina* was generally associated with such symptoms. They have given the details of the morphological characters. In few cases *Diplodia sansevieriae* was also isolated from almost identical spots. The latter organism could, however, be distinguished from it due to its larger and more prominent fruiting bodies.

Morphological characters of *D. sansevieriae* : Hyphae grayish-brown, 1·7–2·9μ wide ; pycnidia thick walled, black generally globose about 200μ in diameter ; conidia hyaline and single-celled when young, at maturity they assumed dark brown colour and some of them became bicelled 20–26 × 13–15μ.

Fusarium semitectum was also isolated from this host. The symptoms produced by this organism were different. The spots were usually of smoke gray colour and generally they started from the margins of the leaves. Due to the difference in the colour of the spots and on account of the absence of black fruiting bodies (pycnidia) the lesions produced by this organism could easily be distinguished from those produced by *Phyllosticta* or *Diplodia*.

Morphological characters of *Fusarium semitectum* : Hyphae thin, white, septate 1·7–2·0μ wide ; chlamydospores intercalary, in chain (2·0 × 2·0) ; sporodochia absent ; macroconidia spindle or sickle shaped, very variable in size, may be one to six septate.

One septate	...7–20 × 2–4μ	
Two septate	...15–40 × 3–5·5μ	
Three septate	...23–50 × 3–6μ	most common.
Four septate	...25–58 × 3·6–7μ	
Five septate	...28–62 × 3·6–7·5μ	
Six septate	...36–72 × 4–7·5μ	

microconidia non-septate 4–13 × 1·6–3·5μ

The viability of conidia and other particulars about the above three organisms are summarized in Table 1.

TABLE 1

Showing the conidial viability and other particulars of the three fungi isolated from the diseased leaves of *S. macrophylla*.

Particulars	Organisms		
	P. cycadina	*D. sansevieriae*	*F. semitectum*
1. Viability of conidia	12 months	13½ months	7 months
2. Percentage of infection on artificial inoculations	75%	40%	70%
3. Cross inoculation were successful on	*Cycas revoluta C. rumphii* and *Sansevieria cylindrica*	*Pithecolobium dulce* and *Eriobotry japonica*	None
4. Cross inoculation failed on	All other hosts susceptible to *Phyllosticta* species	*Typha latifolia, Smilax macrophylla* and *Dalbergia sissoo*	*Citrus grandis Carica papaya, Cajanus cajan.* and *Gossypium* sp.

24. **Smilax macrophylla** Roxb.

Family—Liliaceae

Organism : *Botryodiplodia theobromae* Pat.

B. theobromae was obtained from the diseased leaves of this host in December, 1960. The leaves exhibited violet slate spots which were mostly scattered and limited from either side by the midrib. Few sparse pycnidia were also visible in severely diseased portions. By March the infection had spread to a large number of leaves and in some cases, brittle and fragile portions had been detached. Defoliation of severely infected leaves was also quite common. The morphological characters of the isolate were similar to those described earlier.

Viability of the conidia—11 months.

Artificial inoculations caused infection to 60% leaves.

The organism easily infected the leaves of *Nephelium litchi*, *Mangifera indica*, *Sansevieria macrophylla* and *S. cylindrica*. It failed to infect the leaves of *Dracaena terminalis*, *Ficus glomerata* and *F. religiosa*.

So far *Botryodiplodia theobromae* was not reported on this host.

The culture is deposited in C. M. I., Kew and Botany Department, University of Allahabad (India).

Locality—Botanical Gardens, University of Allahabad.

25. **Typha latifolia** L.

Family—Typhaceae.

Organisms : (1) *Curvularia verruculosa* Tandon et Bilgrami.

It was observed in May, 1960 that the plants of *T. latifolia* growing in the Botanical Gardens, University of Allahabad, were exhibiting light brown elongated streaks on the lamina. It was noted that in the earlier stages the browning started from the centre of the leaves and proceeded both towards its tip as well as the base. In case of serious infections the affected areas dried up. The diseased portions never separated from the healthy parts but they merely lost their rigidity. Even a slight mechanical jerk caused a permanent bent in the diseased region of the leaf. Isolations yielded richly sporulating, light brown colonies of *Curvularia verruculosa*. The morphological characters of the isolate were similar to the isolate recovered from the leaves of *Cycas rumphii*.

(2) *Diplodia typhina* Sacc.—Certain elliptical or semicircular, ash coloured lesions were also observed about the same time. Those spots were scattered and they were restricted in number as well as in area. Their maximum length was upto 3·5 cm and breadth 1·5 cm. By the end of July black pycnidia were distinctly perceptible in the diseased areas. Pycnidial development was usually in vertical rows. By December the affected tissues turned brittle and fragile, after which they dissociated in small fragments. *Diplodia typhina* was isolated from such spots.

Morphological characters of the isolate : Hyphae light grayish, about 4·5μ wide ; pycnidia globose, dark gray, 175–315μ × 152–290μ filled with numerous ovoid conidia ; conidia hyaline and unicellular when young, bicelled and dark brown at maturity, 12–17 × 5–7μ.

This is the first report of *D. typhina* from India.

(3) *Periconia saraswatipurensis* Bilgrami.—The fungus was first observed on this host in October 1960 in the village Saraswatipur (about 10 miles North-west of Allahabad). The organism developed black colonies, of about 0·3 cm in diameter over the dead tissues of the host. Microscopic examination of the colonies showed the presence of numerous globose, echinulate conidia of dark brown colour. In culture the colonies were initially light green in colour, ten to fifteen days old cultures started producing conidia in large numbers due to which the surface of the colonies were covered with a powdery sooty mass.

Morphological characters of the isolate : The Stipe septate (upto 10 septa) thick walled and dark brown when mature. Average distance between each septum in the basal region was about 30μ but the maximum length was 240μ and the breadth was 8–10μ. Occasionally the width at the point of septation was slightly greater. Conidia, lateral or terminal (Plate IV, fig. 5). The lateral chain of conidia usually appeared from the points of septations of the the main stipe. The chain was usually smaller towards the apical end of the stipe, while in the basal region it was branched and bigger. The conidia were directly borne on the main stipes which were always unbranched. The conidia developed in acropetal chains, maturing from apex downwards, single-celled, dark brown, globose, distinctly verrucose, 6–8·5μ in diameter.

The conidial viability and other particulars of the three fungi isolated from the leaves of *Typha latifolia* are summarized in Table 2.

TABLE 2

Representing the conidial viability and other particulars of the three organisms isolated from the leaves of *T. latifolia*.

Particulars	Organisms		
	Curvularia verruculosa	*Diplodia typhina*	*Periconia saraswatipurensis*
Conidial viability	7½ months	11 months	10 months
Percentage of leaves infected on artificial inoculation	56%	45%	No
Cross inoculations were successful on	*Cycas rumphii* and *Anona squamosa*	None	None
Cross inoculations failed on	*Pennisetum typhoideum* and *Sorghum vulgare*	*Grevillea robusta*, *Mangifera indica*, *Smilax simplex*, *Dalbergia sissoo* and *Sansevieria macrophylla*	*Oryza sativa*, *Caesalpinia pulcherrima*, *Pennisetum typhoideum* and *Sorghum vulgare*

Locality—Botanical Gardens, University of Allahabad ; Village Saraswatipur

Discussion :

On the basis of the present studies it can be stressed that a more through probe and serious attention should be directed towards the organism which are responsible for the leaf spot diseases. An intensive search reveals that fungi representing diverse taxonomic position are sometimes in close intimacy with each other in particular localized areas of the disordered foliage. Generally an infected portion under the microscope displays the presence of conidia of several micro-organisms. The primary task therefore, lies in ascertaining the type of relationship which they have with their hosts and in assessing the extent of damage caused by them. Due to extensive and common occurrence of these diseases, the chances for finding new fungi in their association are always great. The present observations showed that invasion of new hosts by known forms was also quite consistent. The conidia of Sphaeropsidales possessed maximum viability (6–13 months). They were followed by Melanconiales where the spores retained their germination capabilities upto 11 months (*Colletotrichum capsici* on *Pothos scandens*). The conidial viability of the Moniliales was shortest and it lasted for a maximum period of eight months only (*Alternaria tenuis* on *Dahlia rosae* and *Nigrospora sphaerica* on *Ficus krishnae*). It appears that to a certain degree the conidial viability of pathogenic fungi is dependent on their taxonomic position. Variations in the nature of their fructification seem to influence this aspect of life. The present investigations also manifested that the viability of spores of particular species varied considerably on difierent hosts. *Colletotrichum capsici* was recovered from two ornamental plants *viz.*, *Quisqualis indica* and *Pothos scandens* but the longevity of its spores was 11 months on the former and $9\frac{1}{2}$ months on the latter. Some species of *Phyllosticta* also exhibited similar pronounced variations. A detailed study in this direction might be of profound interest as several factors like constituents of the host, texture of the leaves and position of the fruiting bodies over the host may be responsible for such differences.

An unrestricted capacity on the part of the leaf spot pathogens to attack a number of different hosts appears to enhance their life and chances for propagation. Artificial cross inoculations showed that species of *Phyllosticta*, *Pestalotiopsis*, *Colletotrichum*, *Curvularia*, *Alternaria* and *Nigrospora* were capable of infecting several such hosts where the viability of their spores was prolonged. It is therefore, alway desirable to evaluate the conidial life on other susceptible hosts.

Summary :

The symptoms of the leafspot diseases of twentyfive common ornamental plants have been described. Pathogenicity of the organisms was established and the viability of their conidia was determined. The host range of different pathogens was also studied. Five new species have been described. *Phyllosticta glaucispora* Delac ; is a new record from India. *Fusarium sambucinum*, *F. semitectum*, *Dictyoarthrinium sacchari*, *Nigrospora sphaerica*, *Botryodiplodia theobromae*, *Collectotrichum capsicis*, *Chaetomium funicola* and *Alternaria tenuis* were recorded on new hosts.

Acknowledgements :

The author is grateful to Professor R. N. Tandon for his valuable suggestions.

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EXPLANATION OF THE PLATES

PLATE I.

Fig. 1. Showing scattered spots produced by *Phyllosticta bauhiniae* over the leaves of *Bauhinia purpurea*.

Fig. 2. Microtome T. S. of *Cycas revoluta* leaflet showing the pycnidia of *Phyllosticta cycadina* (X 316).

Fig. 3. Microtome T. S. of *Cycas revoluta* leaflet showing the perithecia of *Teichospora indica* (X 316).

Fig. 4. Showing the ruptured perithecia with numerous asci and ascospores of *Teichospora indica* (X 134).

Fig. 5. Showing the bulbil of *Cycas revoluta* which was placed in sterilized glass chambers to obtain the perfect stage.

Fig. 6. Showing the conidia of *Alternaria tenuis*, arranged in chains (X 506), recovered from the infected leaves of *Dahlia rosae*.

PLATE II.

Fig. 1. Showing the symptoms of the disease on the leaf of *Dracaena terminalis* caused due to infection of *Phyllosticta dracaenae*.

Fig. 2. Showing closely septate nature of the conidiophores of *Dictyoarthrinium sacchari* (X 410).

Fig. 3. Showing the reticulate nature of the conidial walls of *D. sacchari* (X 672).

Fig. 4. Showing the diseased leaves of *Ficus krishnae* due to infection of *Nigrospora sphaerica*

Fig. 5. Showing spherical conidia of *Nigrospora sphaerica* (X 347) obtained from the leaves of *Ficus krishnae*.

Fig. 6. Showing the conidia of *Botryodiplodia theobromae* (X 571).

PLATE III.

Fig. 1. Showing the conidia and conidiophores of *Acrospeira fluctuata* (X 80) ; recovered from the infected leaves of *Monstera deliciosa*.

Fig. 2. Showing the conidia of various configurations of *A. fluctuata* (X 410).

Fig. 3. Showing the spores of *Sphaeropsis nyctanthis* (X 46).

Fig. 4. Showing the spores of *Sphaeropsis nyctanthis* (X 410).

Fig. 5. Showing a portion of infected leaf of *Pandanus tectorius* caused by *Phyllosticta pandanicola*.

Fig. 6. Showing the diseased leaves of *Pithecolobium dulce*.

PLATE IV.

Fig. 1. Showing the elongated setae of *Colletotrichum dematium* (X 46).

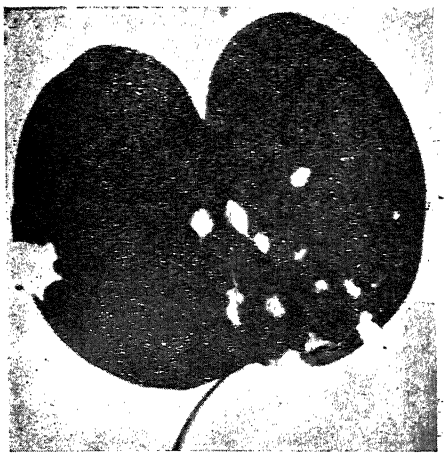
Fig. 2. Showing elongated and slightly curved setae of *Colletotrichum capsici* (X 80).

Fig. 3. Showing the dichotomously branched perithecial appendages of *Chaetomium funicola*.

Fig. 4. Showing scattered spots over the leaf of *Sansevieria macrophylla* caused due to infection of *Phyllosticta cycadina*.

Fig. 5. Showing the conidia and conidiophores of *Periconia saraswatipurensis* (X 143).

PLATE I



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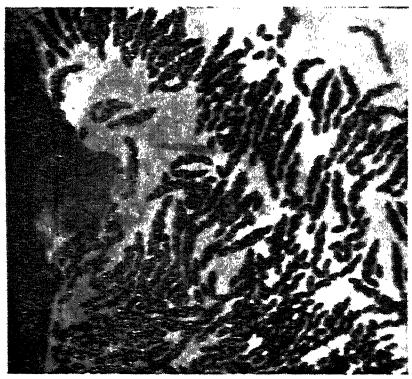

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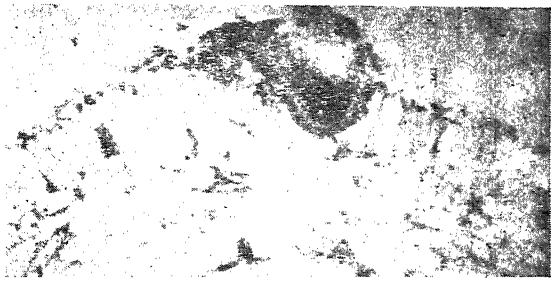


Fig. 2

Fig. 5

Fig. 3

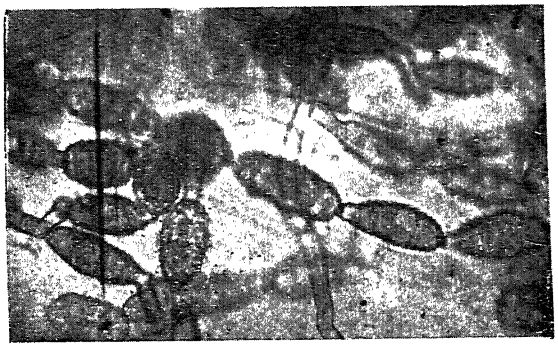
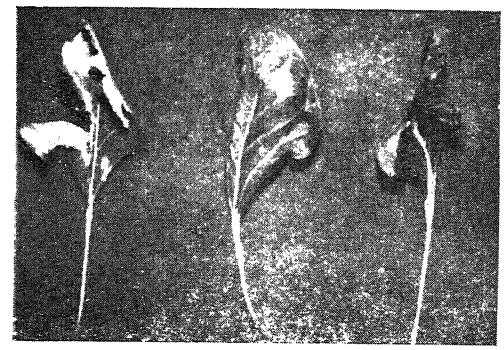


Fig. 6

PLATE II

Fig. 1



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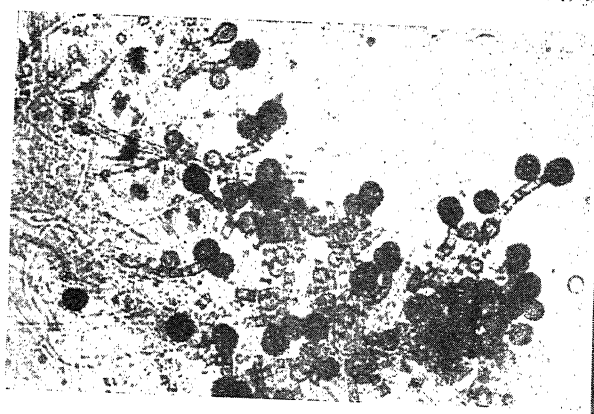

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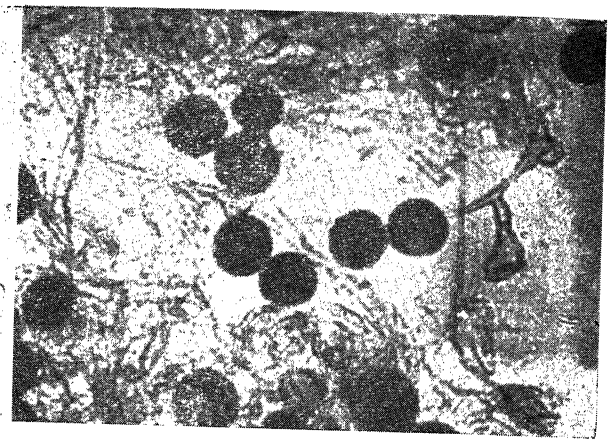

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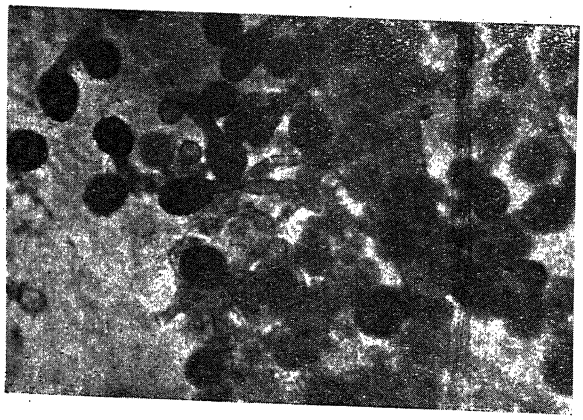

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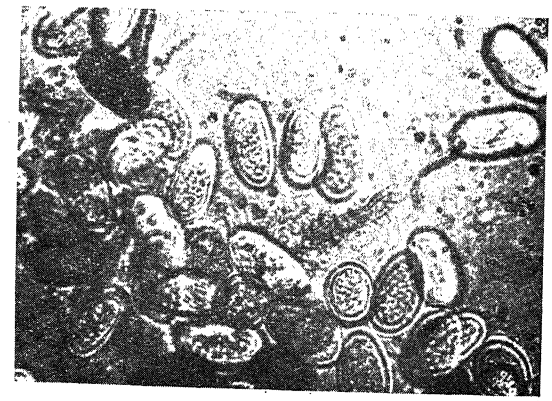
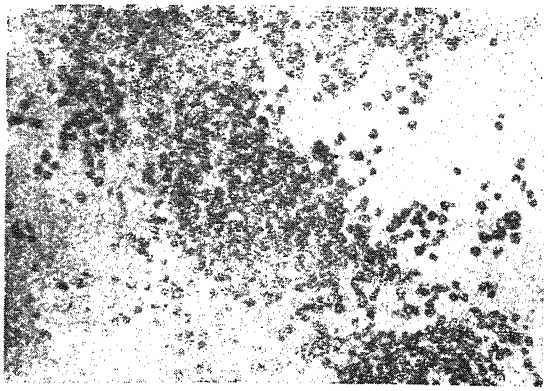


Fig. 6

PLATE III



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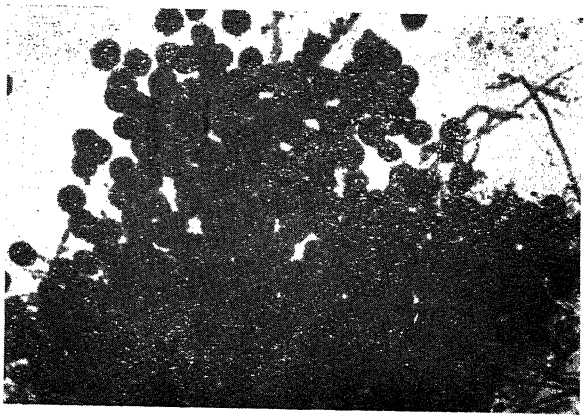

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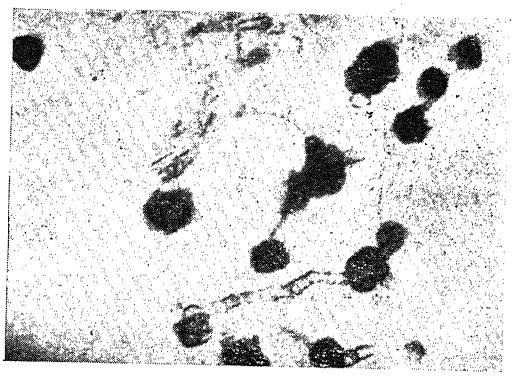


Fig. 2

Fig. 5

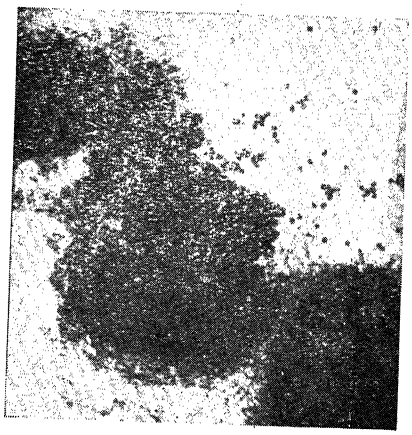
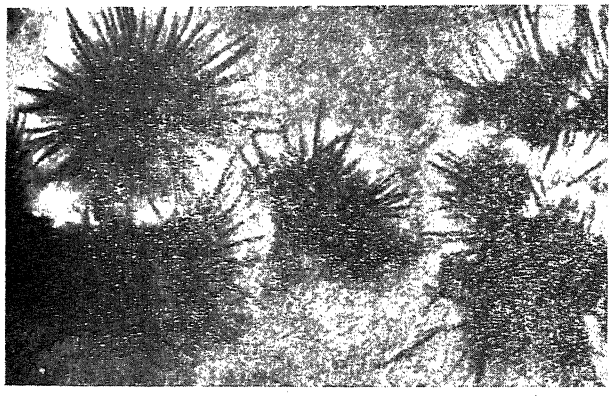


Fig. 3

Fig. 6

PLATE IV



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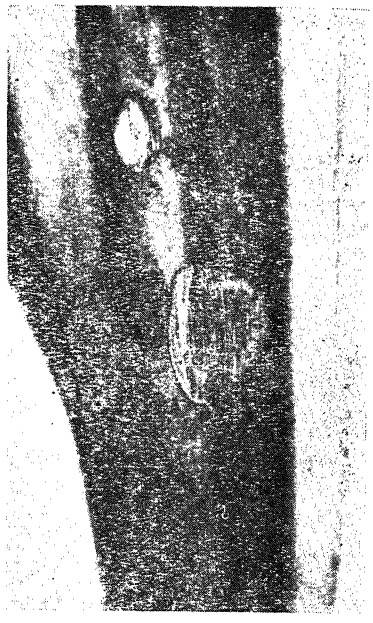

Fig. 4

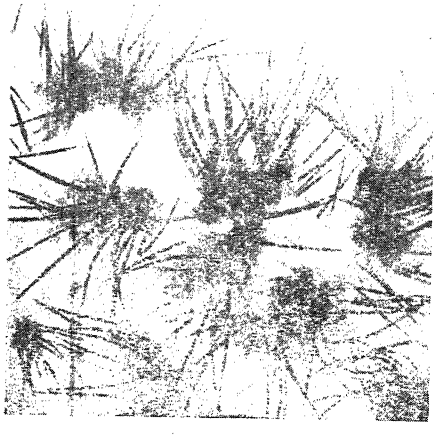

Fig. 2

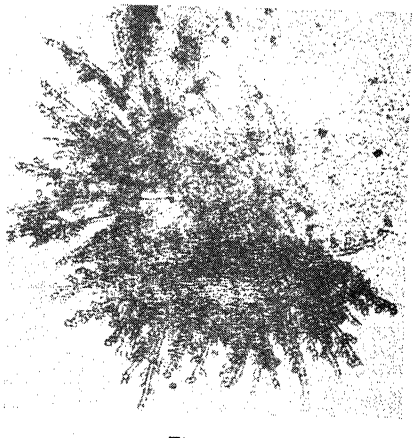

Fig. 5

Fig. 3

PHYSIOLOGICAL STUDIES ON SALT-TOLERANCE IN CROP PLANTS. XIX EFFECT OF SODIUM CARBONATE ON GROWTH AND MATURITY OF WHEAT AND GRAM AND INDUCING TOLERANCE BY PRETREATMENT OF SEEDS

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[Received on March 17, 1962]

Introduction :

In arid and semi-arid regions of India, vast streches of land are rendered unfit for profitable cultivation due to soil alkalinity. Bringing such patches of land under plough had always been quite a serious problem to the cultivator. Some soil ameliorative measures like addition of gypsum, green manuring or cultivation of rice have been suggested to reclaim extremely alkaline 'usar' soils, yet the problem of improving crop production in low or moderately alkaline areas has often been overlooked as no external symptoms of injury are visible. Much less the physiological activities of different crop plants growing in these areas were studied ; though the problem of salt-tolerances has been under investigation for the past two decades at Regional Salinity Laboratory (U. S. A) and has been reviewed in its various aspects by Hayward and Wadleigh (1949) Hayward and Bernstein (1958) and Bernstein and Hayward (1958).

As pointed out by Russel (1950) the injurious effect on plants growing in alkali soils can be due to sodium carbonate, though present in low concentrations ; attempt has been made to study the relative tolerance of wheat and gram to sodium carbonate. Also, the possibility of inducing tolerance by pretreatment of seeds has been explored.

In the present investigation, the effect of adding the salt to the soil at the sowing time on crop growth and yield has been studied in pot cultures. The plants were grown with optimum water supply throughout or by subjecting the plants to repeated soil-droughts by stopping watering during the phase of vigorous plant growth or of maturity. The treatment of soil drought was introduced to simulate the local conditions in western Uttar Pradesh as the crop usually experiences the dry weather during the season.

Material and Methods :

Pot culture.—2·5 Kilograms of air-dry garden soil mixed with leaf compost (1 : 1) was filled in earthen pots (9″×9″). 10 seeds were planted in each pot, and Na_2CO_3 was added in aqueous solution immediately after the sowing. Necessary precutions were taken to collect the percolating soil solution from the pots and add it back to the same. At four weeks after sowing seedlings were thinned to four in each pot.

Seed-treatment.—Grains of wheat C. 591 and seeds of gram N. P. 28 were soaked (partly immersed) in solution of Na_2CO_3 (300 ppm) in petri-dishes without filter

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paper for a period of 24 hours either continuously or intermittently, the latter comprising of three cycles of 8 hours soaking followed by 16 hours of drying in shade in atmosphere with relative humidity of 80–90 percent, and were immediately sown in the pots, wherein Na_2CO_3 at 0·03 percent concentration (on air dry soil) was added soon after sowing the seeds. Control represented the untreated seeds which were sown a day earlier.

Soil-droughts.—When plants were vigorously growing (9th to 12th week) or maturing (13th to 16th week), one set at each stage was subjected to permanent wilting stage four to five times by stopping watering till the moisture percentage of the soil reached about 6% ; thus soil moisture in these pots varied from field capacity (about 25%) to 6%, while optimum water supply was maintained throughout in another set wherein soil moisture varied from 25% to 17%.

Observations.—Records on the height of the main shoot at maturity, shoot-dry-matter (minus grain or seed) at harvest, yield of grains or seeds and 100 grain or seed weight were made, and the results were analysed statistically according to analysis of variance, on factorial basis. The critical difference at 5% probability is tabulated along with the 'means' where the treatments were significant.

Experimental Findings.

Experiment I. Effect of sodium carbonate on growth and maturity of wheat and gram.

Plan of the experiment :

Crop and variety : Wheat C. 591 and gram N. P. 28.

Salt-level (on air dry soil) : 0%, 0·01% and 0·03% Na_2CO_3.

Soil-moisture : (*i*) Optimum ;

(*ii*) Soil-droughts from 9th to 12th week.

(*iii*) Soil-droughts from 13th to 16th week.

Replications : Eight.

The results on growth and yield of the two crops are dealt with separately and are presented in tables 1 and 2.

TABLE 1

Effect of Na_2CO_3, added to the soil, on growth and yield of wheat C. 591

Observation	Soil — Optimum throughout			Soil — Soil-droughts (9th–12th week)			Water — Soil-droughts (13th–16th week)			Supply C.D. at 5% level
	Na_2CO_3 added to the soil									
	0·0	0·01	0·03	0·0	0·01	0·03	0·0	0·01	0·03	
Height (cm)	75·1	70·4	65·6	71·4	62·1	52·2	57·7	65·1	58·6	3·80
Shoot-dry-weight (g)	2·33	2·16	1·66	2·60	1·96	1·35	1·28	1·22	1·03	0·60
Grain-yield (g)	1·64	1·50	0·92	1·35	1·09	0·44	0·33	0·34	0·16	0·11
100-grain-weight (g)	3·77	3·25	3·01	3·49	2·82	2·11	1·54	1·26	0·73	0·43

Heights of the plants were depressed both by salt-level as well as soil-droughts. It was interesting to notice that the lower dose of the salt increased the height by 13% over its respective control (*i.e.* with drought) when the plants were subjected to soil-droughts from 13th to 16th week. In the presence of the higher dose of the salt, the leaves dried immaturely especially when the soil droughts were given; burning of leaf tips was observed even in the set with optimum water supply throughout.

Reductions in shoot-dry-matter produced were seen in the 'salt-fed' series even under optimum water supply; the deleterious effect was more pronounced under soil-droughts at the stage when the plants were growing vigorously (9th to 12th week). Relative to control, increase in the salt concentration resulted in lowering of grain yield and of 100-grain weight, and the influence was depressing still further if the plants were subjected to soil-droughts, especially at the time of vigorous shoot growth.

TABLE 2

Effect of Na_2CO_3 added to the soil, on growth and yield of gram No. P. 28.

Observation	Soil — Water — Supply									
	Optimum throughout			Soil-droughts (9th-12th week)			Soil-droughts 13th-16th week)		C. D. at 5% level	
	Na_2CO_3 added to the soil									
	0·0	0·01	0·03	0·0	0·01	0·03	0·0	0·01	0·03	
Height (cm)	40·4	41·4	41·2	40·3	42·0	36·4	34·1	42·0	41·7	4·3
Shoot-dry weight (g)	2·21	1·77	1·75	1·74	1·71	0·87	0·92	1·19	0·69	0·40
Seed-yield (g)	1·01	0·71	0·55	0·45	0·68	0·45	0·12	0·15	0·92	0·26
100-seed weight (g)	11·56	8·75	10·80	8·96	12·54	9·91	6·74	7·27	0·61	2·60

Depressing influence of Na_2CO_3 on the height of plants was not evident when the water supply was maintained at the optimum level; however, under soil droughts from 9th to 12th week a reduction of about 10% by the higher dose was noted. Dry matter produced by the shoots, under optimum watering, was reduced by 20% and 21% in the lower and the higher doses respectively; but under soil-droughts from 9th to 12th week a reduction of 50% was obtained by the higher dose. However, with soil droughts from 13th to 16th week, the deleterious effect of the salt was not seen.

Trends similar to dry matter production were evident for the yield of seeds. Reduction of 30% and 46% were noticed for lower and higher doses of the salt under the conditions of optimum watering, while such an influence was not seen for the sets subjected to soil droughts either from 9th to 12th week or from 13th to 16th week; although a tendency for further reduction in yield by the salt (0·03%) was evident under the late drought conditions. It may be pointed out that the salt effect under soil droughts was not evident. Soil-droughts alone, especially from 13th to 16th week, reduced the seed-yield considerably.

100-seed-weight was affected rather erratically. Under optimum water-supply a reduction of 24% was seen by the higher dose of the salt. Soil droughts from

9th to 12th week resulted in an improvement by 11%. Again a reduction of 91% was noticed under soil droughts from 13th to 16th week.

Experiment II. Inducing tolerance to sodium carbonate by pretreatment of seeds.

Plan of the experiment :

Crop and variety : Wheat C. 591 and gram N. P. 28

Salt-level (on air-dry soil) 0·03% Na_2CO_3

Seed treatments : Soaking for 24 hours in 300 ppm of Na_2CO_3 solution.

(*a*) Continuous ; and

(*b*) Intermittent.

(II) Control (untreated seeds)

Soil moisture : (*i*) optimum throughout

(*ii*) Soil-droughts from 13th to 16th week after sowing

Replications : Eight

Results obtained for wheat and gram are separately explained and are furnished in tables 3 and 4 below.

TABLE 3

Influence of presowing seed-treatments on growth and yield of wheat C. 591 grown in soil containing 0·03% (on air dry soil) sodium carbonate.

	Soil — Water — Supply						
	Optimum throughout			Soil-droughts (13th–16th week)			
Observation	Control	Continuou	Intermittent	Control	Continuous	Intermittent	C.D. at 5% level
Height (cm)	72·4	71·3	68·5	53·5	58·3	49·1	4·5
Shoot-dry weight(g)	2·69	1·42	2·13	1·73	1·19	0·69	0·51
Grain-yield (g)	2·08	1·01	1·57	0·64	0·64	0·22	0·32
100-grain weight(g)	3·66	3·38	3·43	2·46	2·56	3·12	0·90

It would be seen that pretreating the seeds with Na_2CO_3 solution was not conductive in improving the height of the plants ; reduction in height was noticed with 'intermittent' soaking. Soil-droughts, in general, depressed the height. Dry matter produced by the shoots was markedly decreased ; under optimum water supply reduction was relatively more by continuous soaking (47% reduction as compared to 21% reduction by intermittent soaking), while it was the reverse under soil droughts (60% and 31% reductions intermittent continuous soaking respectively). Yield of grain was also depressed ; under optimum watering reduction was relatively higher with continuous soaking (51%) than the intermittent one (24%), while under soil-droughts continous soaking gave yield at par with its control but significant lowering (66% reduction) was noted by intermittent soaking. 100-grain weight was not influenced by the seed-treatments ; however, reduction by soil droughts, irrespective of seed treatments, was evident.

TABLE 4

Influence of presowing seed-treatments on growth and yield of gram N. P. 28 grown in soil containing 0·03% (on air dry soil) of sodium corbonate

Observation	Soil — Optimum throughout			Water — Soil-droughts (13th–16th week)			Supply
	Presowing soaking seed-treatments						
	Control	Continuous	Intermittent	Control	Continuous	Intermittent	C.D. at 5% level
Height (cm)	40·2	36·4	32·9	39·4	33·6	32·6	3 6
Shoot-dry weight (g)	1·44	0·87	1·16	0·59	0·72	1·01	0·29
Seed-yield (g)	0·93	0·70	0·76	0·40	0·69	0·15	0·29
100-seed weight (g)	14·99	10·67	0·43	0·78	3·52	4·56	1·67

The depressing influence of the seed-treatments, irrespective of soil-water-supply, on height of the plants was quite evident. Under optimum water supply either of the seed-treatments resulted in lowering of dry matter accumulated by the shoots, but under the influence of the soil-droughts an increase of 71% was obtained by intermittent soaking in corbonate solution.

Yield of seed and also 100 seed-weight were depressed by the soaking treatments under the conditions of optimum watering. On the contrary, increases in yield of seed and of 100 seed-weight were obtained by continuous soaking in carbonate solution when the plants were subjected to the influence of soil-droughts.

Discussion :

The specific toxic influence of carbonate and bicorbonate ions on plant growth has generally been agreed upon. Heller *et al* (1940) pointed out that presence of $NaHCO_3$ in water, used for growing tomatoes in sand cultures, was found to be much more injurious than NaCl. Wall and Hartman (1942) attributed the high taxocity of $NaHCO_3$ to high pH value of the solution. The high taxicity could largely be eniminated by neutralising the solution to pH 5·6 to 6·0 with H_2SO_4 (Hageman and Hartman 1941). On the other hand, Gauch and Wadleigh (1951) indicated specific toxic effect of HCO_3 ion ; thus confirming their earlier results that Na_2SO_4 and NaCl added to the control nutrients solution at levels isosmotic to $NaHCO_3$ treatments had a comparatively small effect in depressing growth of red kidney beans. Further, Wadleigh and Brown (1952), working on bean plants, suggested that primary effect of HCO_3 ion was through its effect on protoplasmic consistency of the absorbing cells of the root so that these plants showed an accentuated accumulation of monovalent cations and a depressed accumulation of divalent cations. These authors (Brown and Wadleigh 1955) further added that in garden beets chlorophyll content of the leaves was inversely related to the level of bicorbonate in the substrate. Also, Steward and Preston (1941)

reported that bicorbonate and corbonate anions have a unique effect on respiration, protein and carbohydrate metabolism.

The adverse influence of supply Na_2CO_3 solution on seedling growth and metabolism in wheat and gram was observed by the author as well (Bhardwaj and Rao 1960, and Bhardwaj 1960 and 1961). Apart from depressing the early seedling growth (0–96 hours after sowing), respiration rate, catalase activity, protein-nitrogen and the reducing sugars were affected, thus establishing the specific toxic effect of carbonate via respiration, protein and carbohydrate metabolism.

In the present study, sodium carbonate added to the soil even at 0·03% concentration (on air-dry basis) was definitely harmful to growth and maturity of wheat and gram. It would be seen from text figure 1 what with optimum water supply both growth and yield of the two crops were almost equally depressed by the salt, but with soil-droughts during the vigorous growth period (9th to 12th week after sowing) the effect was more adverse to wheat than gram regarding grain yield alone, and with later soil-droughts (13th to 16th week) gram suffered more than wheat.

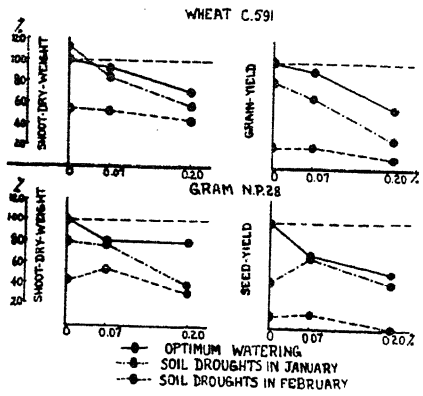

Fig. 1

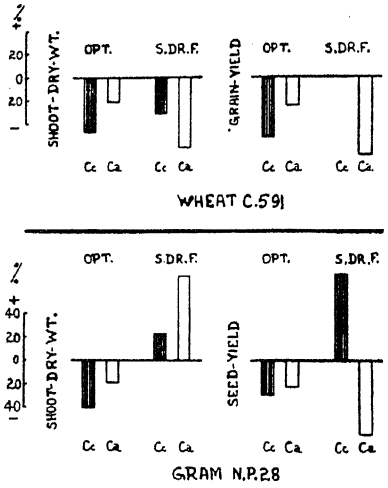

Fig. 2

Text. fig. 1. Effect of sodium carbonate, added to the soil, on shoot-dry-weight at harvest and yield of wheat C. 591 and gram N. P. 28 (expressed as percentage on control—no salt added to the soil).

Text. fig. 2. Influence of presowing seed-treatments on shoot-dry-weight at harvest and yield of wheat C. 591 and gram N. P. 28 grown in soil containing 0·03 percent of sodium carbonate (Expressed as percentages on control—untreated seeds).

OPT : Optimum water supply throughout ;
S. DR. F. : Subjected to soil-droughts from 13th to 16th weed after sowing.
Cc : Continuous soaking for 24 hours in 300 ppm Na_2CO_3 solution.
Ca : Intermittent soaking for 24 hours (3 cycles of 8 hours soaking followed by 16 hours drying) in 300 ppm of Na_2CO_3 solution.

Pretreatment of seeds appeared to have failed to induce tolerance to sodium carbonate, as would be seen in text figure 2. With optimum water supply, the presowing seed-treatment was not favourable to both wheat and gram ; continuous

soaking resulted in greater depression compared to that by intermittent soaking. However, under the condition of soil-droughts during maturity stage (13th to 16th week) the influence of the seed treatments was not similar in the two crops. In wheat continuous soaking in Na_2CO_3 solution resulted in decrease in production of dry matter by the shoots but grain yield was not affected, while intermittent soaking depressed both the characters. In gram continuous soaking led to improvement in growth and yield, while with intermittent soaking seed yield was decreased although dry matter produced by the shoots was higher compared to the control.

Finally, it may be added that the toxic effect of carbonate was evident from the chlorosis and drying of immature leaves. Pretreatment of seeds was ineffective in inducing tolerance to sodium carbonate ; intermittent soaking under the conditions of soil-droughts at the maturity stage was found deterimantal to both the crops, while continuous soaking improved the growth and yield in gram alone.

Summary :

Effect of sodium carbonate added to the soil at 0·01% and 0·03% concentrations, on growth and muturity of wheat and gram was investigated under pot cultures. The results indicate that the presence of the salt even in 0·3% concentration (on air dry soil) was definitely deleterious to the growth of two crops. Under optimum water supply, the crop differences in relation to their tolerance to the carbonate were not clear ; with soil-droughts at the stage of vigorous plant growth (9th to 12th week after sowing), gram was less susceptible than wheat ; later droughts at the maturity stage (13th to 16th week) resulted in greater depression in gram than in wheat. The toxic effect was apparent from chlorosis, tip-burn and premature drying of the leaves in the 'Carbonate' series.

Experiment to induce tolerence to Na_2CO_3 by pretreating the seed failed to indicate promising results. Under favourable water supply, these treatments were definitely harmful ; with soil-droughts at the maturity stage, continuous soaking of seeds in carbonate solution was apparently beneficial to gram.

Acknowledgements :

To Professor I. M. Rao, Head of Botany Department, Sri Venkateshwara University, Tirupati, the author acknowledges gratefully his guidance and helpful suggestions during the progress of work. His thanks are also due to Prof. S. Sinha Head of Botany Department, Agra College, Agra for providing the facilities and encouragements.

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CONTENTS

Published by Dr. R. K. Saksena, for the National Academy of Sciences, India, Allahabad and Printed by E. K. Raja at The Capital Printing Works, Allahabad

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